DOKUZ EYLÜL UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

ELECTROMAGNETIC IMMUNITY IMPROVEMENT OF FLAT PANEL DISPLAY DRIVER BOARD

by
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July, 2008
İZMİR

ELECTROMAGNETIC IMMUNITY IMPROVEMENT OF FLAT PANEL DISPLAY DRIVER BOARD

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M.Sc THESIS EXAMINATION RESULT FORM

We have read the thesis entitled **"ELECTROMAGNETIC IMMUNITY IMPROVEMENT OF FLAT PANEL DISPLAY DRIVER BOARD"** completed by **İREM DÜVEN** under supervision of **ASSOC. PROF. DR. UĞUR ÇAM** 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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ABSTRACT

Thesis will describe the hardware architecture of a FHD TFT TV (Full High Definition Thin Film Transistor Television) and the effect of different layout structures on the immunity of the television to RF (Radio Frequency) voltages at antenna terminal in details. Thesis also includes brief explanation of flat panel technology and processing blocks. Explanations of building blocks of a television and flat panel display structures are given before design stage. Electromagnetic compatibility (EMC) concept and the test procedures related with the thesis are explained before showing the effects of implementing different layout structures for better understanding of the design. Test reports with different layout structures and improvements are demonstrated. Design steps, considerations of a TV main board and layout solutions for improving the immunity to RF voltages at antenna terminal are defined in details through the thesis.

Keywords: flat panel display, electromagnetic compatibility, immunity, layout

DÜZ PANEL SÜRÜCÜ KARTTA ELEKTROMANYETİK BAĞIŞIKLIK İYİLEŞTİRİLMESİ

ÖZ

Tez tam yüksek çözünürlüklü düz panel ekranlı televizyon anakart tasarımı ve bu kart üzerinde yapılan anten terminalinde radyo frekansı voltaj bağışıklığını geliştirici layout çalışmalarını anlatmaktadır. Düz panel teknolojisi ve işlemci blokları hakkında genel açıklamalar tez kapsamında verilmiştir. Tasarım sürecinin anlatılmasından önce televizyon ve düz panel yapıları hakkında bilgi verilmiştir. Baskı devrede farklı yerleşim uygulamalarının daha net anlaşılabilmesi için elektromanyetik uyumluluk kavramı ve tez konusuyla ilgili test yöntemleri anlatılmıştır. Değişik baskı devre yerleşimleriyle alınan test raporları ve iyileştirmeler gösterilmiştir. Televizyon anakart tasarım aşamaları, kriterleri ve anten terminalinde radyo frekansı voltajlarına karşı bağışıklığı artırıcı baskı devre üzerinde yerleşim çözümleri düz paneller için detaylı olarak belirtilmiştir.

Anahtar sözcükler: düz panel ekran, elektromanyetik uyumluluk, bağışıklık, yerleşim

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CHAPTER ONE

INTRODUCTION

Digital technology fully takes part in TV processing units with the development of flat panel displays. In CRT (Cathode Ray Tube) televisions, analog circuits are used to display pictures on the screen. The advantages of flat panel displays over CRT are larger screen size, higher resolution, lower weight, compatibility with high resolution digital video interfaces. The market for flat panel displays is increased day by day. Flat panel displays can be classified into TFT-LCD and plasma displays. The driving technique of both panels is the same. However, the materials constituting the panel differ. In this thesis, TFT-LCD panels will be under consideration.

Flat panel displays are based on digital technology where the display is formed by pixels which are the smallest unit of the display. The total pixel number defines the resolution of the display. The interface between the video processing board and the flat panel display is via LVDS (Low Voltage Differential Signal) which is a digital high bandwidth signal interface. Flat panel displays are totally digital processing based signals.

Electromagnetic compatibility is the ability of electrical and electronics devices to operate in their electromagnetic environment without suffering from or disturbing other devices. Increasing number of electronic devices and usage of electromagnetic waves for communication has a the necessity to control the emission and immunity of these devices. This necessity gave birth to international organizations which regulate the limits for electromagnetic issues.

In this thesis, the aim is to show the hardware architecture of a FHD FPD (Full High Definition Flat Panel Display) television and the thesis focuses on the improvements on the immunity of the television (TV) to RF (radio frequency) voltages at antenna terminal with different layout structures. Immunity of a TV receiver to RF voltages at antenna terminal is very important for proper operation of the device. This phenomenon occurs in daily life when current is induced on antenna cable due to electromagnetic waves in the environment.

CHAPTER TWO

FLAT PANEL DISPLAY BASICS

Flat panel displays (FPD) are the product of current driving display technology. A flat panel display consists of pixels which are organized as row and columns. Each pixel is divided in three subpixels which are used to give red, green and blue (RGB) colors. The mixture of these three colors with different amounts gives all colors. Actually, FPDs can be considered in two different groups. The first one is liquid crystal display (LCD) and the second is plasma display. Both technologies have different advantages and drawbacks. The basic difference between LCD and plasma display is that the light source of the LCD at the backside of the panel is continuously on and the liquid crystal material controls the light level and color for each behaving like a valve. However, each pixel in a plasma display acts as a separate lamp defining the color and brightness. Concern of this chapter is a brief explanation of FPD basics, panel driving and backlight technologies.

2.1 TFT-LCD Displays

In most cases, TFT (Thin Film Transistor) and LCD (Liquid Crystal Display) are thought as different type of displays which is generally confusing. 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 subpixel. TFT-LCD display is the common name used for display devices using the liquid crystal technology.

2.1.1 LCD Basics

2.1.1.1 Liquid Crystal

Crystals have perfect flat surfaces because of their molecular structures. Crystals, such as quartz, are formed when molecules from a three dimensional matrix by attaching themselves firmly to each other in a regular pattern. They all point in exactly the same direction. Crystals are solid materials actually, but the term liquid crystal is used to describe a substance which is in a state between a liquid and a crystal but exhibits properties similar to both (Morris, 1993). Molecules in liquid crystals tend to arrange themselves until they all point to the same general direction, but at the same time the whole mass can flow like a liquid. Molecular structure of a liquid crystal is shown in Figure 2.1.

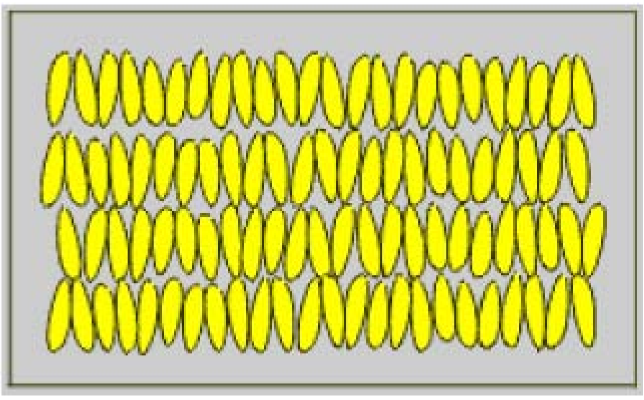


Figure 2.1 Molecular structure of a liquid crystal
(Morris, 1993)

Many chemical compounds exists which has the liquid crystal state. Liquid crystal state can be observed by cooling the liquid or heating the solid state of these special materials. The molecular structure change of liquid crystal material is shown in Figure 2.2 depending on the temperature.

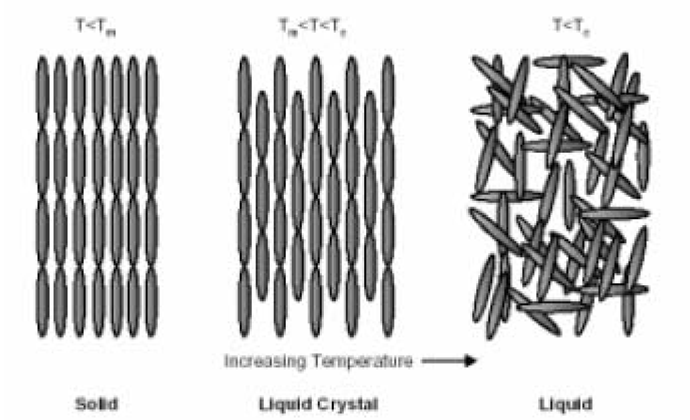


Figure 2.2 Molecular structure of liquid crystal depending to temperature (Morris, 1993)

2.1.1.2 Twisted Nematic (TN)

LCDs are the most popular product in display market currently and they are used in several products ranging from small size displays used in cell phones to large size displays used in TV sets. Although there are several types of liquid crystal material, nematic crystals are the most commonly used in display devices.

Nematic material is rod phisycal shaped and alignment of the crystal varies depending on to electric field. The alignment of the cell without and under electrical field is shown in Figure 2.3 respectively.

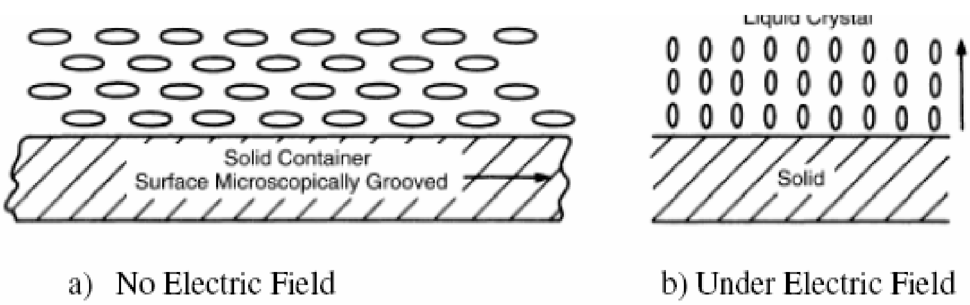


Figure 2.3 Alignment of the liquid crystal depending to electric field (Morris, 1993)

The alignment of rods change under electric field after a critical value but the alignment change is not abrupt. The variation has a transfer curve and the three stages of the rods under electric field are given in Figure 2.4 (Morris, 1993). Shapes given in Figure 2.4 are for

- Without electric field
- Under twice the critical electric field
- Under several times of critical electric field applied.

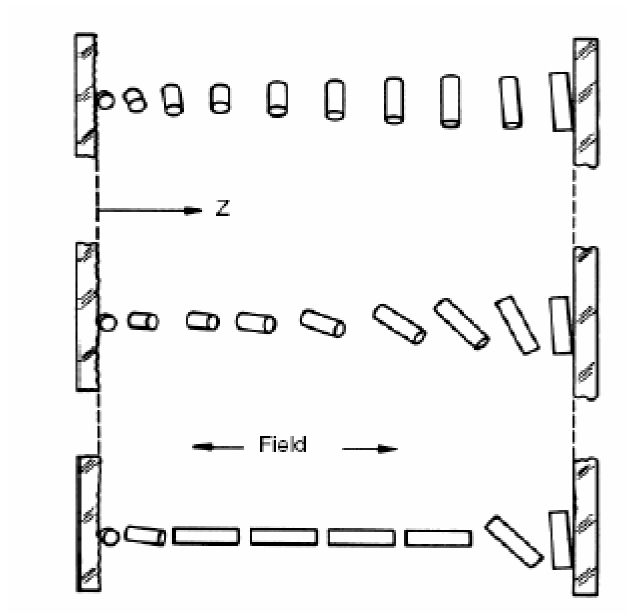


Figure 2.4 Alignment of rods under increasing electric field (Morris, 1993)

Vertical alignment varies with electric field and the horizontal alignment of the rods is defined by groove direction of the solid plate at the top and bottom side. Twisted nematic architecture uses this feature. The top and bottom plates are grooved orthogonally and the horizontal position of nematic is ninety degree shifted between plates. Twisted nematic structure between grooved plates is given in Figure 2.5.

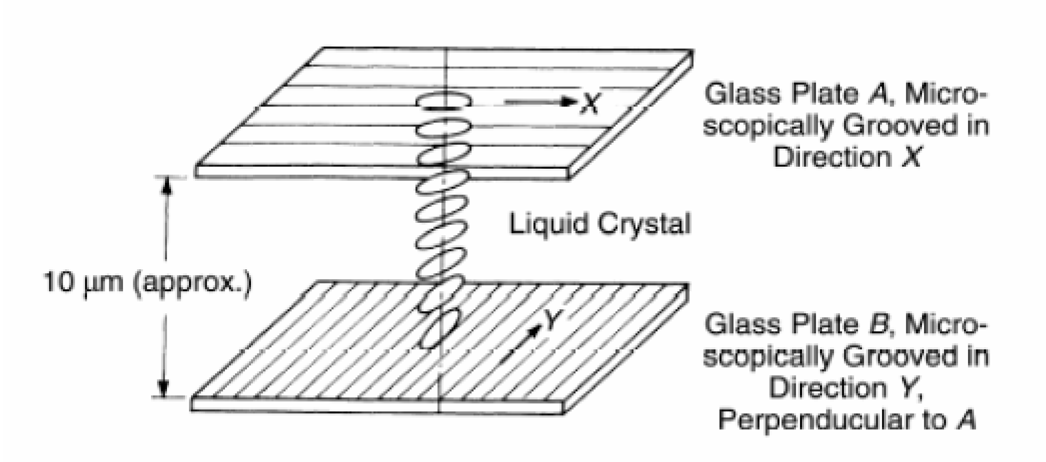


Figure 2.5 Twisted nematic architecture between grooved plates (Gökkaya, 2007)

Nematic and twisted nematic structures are explained before for better understanding of display operation which is based on twisted nematic architecture.

The operation of twisted nematics in a LCD can be explained with the help of Figure 2.6.

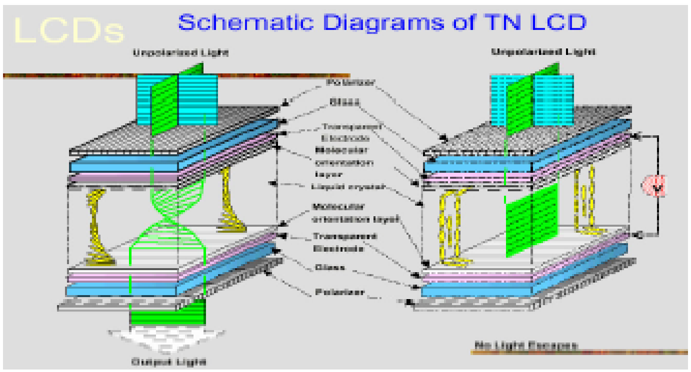


Figure 2.6 Twisted nematic technology in a display

The electrode plates at the top and bottom side are grooved orthogonally. LC material horizontal alignment at the surface of a plate is in the same direction and there is ninety degree phase shift between two plates. For normally on panels, rear polarizer and front polarizer are orthogonal. Under the condition of no electric field applied to LC material, light polarization shifts ninety degree during passing through the LC. Then the phase shifted light can pass through front polarizer and displayed on the screen. For normally off panels, the polarizers are at the same direction (not orthogonal). In case of no electric field applied, no light can pass through and black is displayed on the screen.

2.1.2.3 Super Twisted Nematic (STN)

STN is the modified version of TN. Phase shift of light while passing through STN technology is 270 degree. LC phase shifts down to 180 degree when electric field is applied to the material. The alignment of LC material in STN architecture is given Figure 2.7.

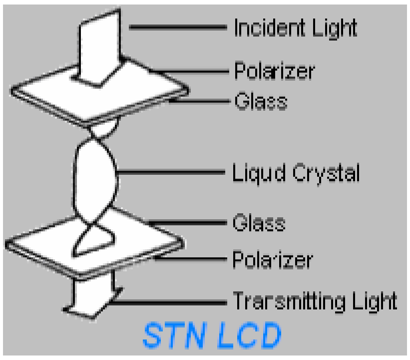


Figure 2.7 Alignment of LC material in STN structure (WEB_2, 2007)

The basic advantage of this architecture is the control of LC material is more sensitive to applied voltage. Considering the storage capacity charge and discharge time needed in STN technology will be lower than TN because the voltage variation will be lower in STN. This means that the response time, i.e. transition from black to white, is lower. The relative transmission level of light due to voltage variation on LC material diagram is in Figure 2.8.

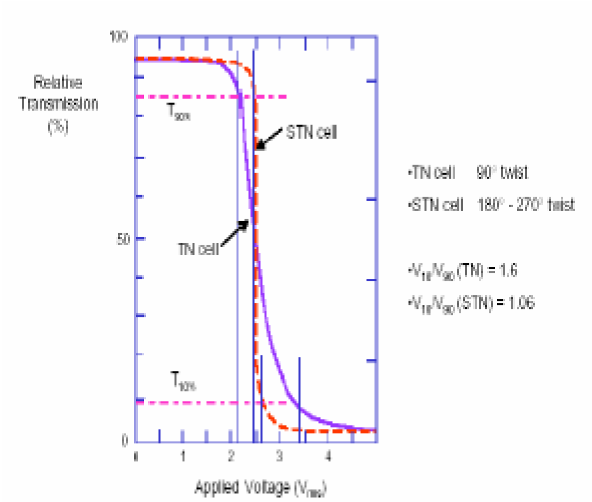


Figure 2.8 Relative light transmission level depending to voltage applied for TN and STN (WEB_2, 2007)

2.1.2 Principles of LCD Operation

The structure of an LCD is given in Figure 2.9. The operation of the LCD is explained with the help of Figure 2.9.

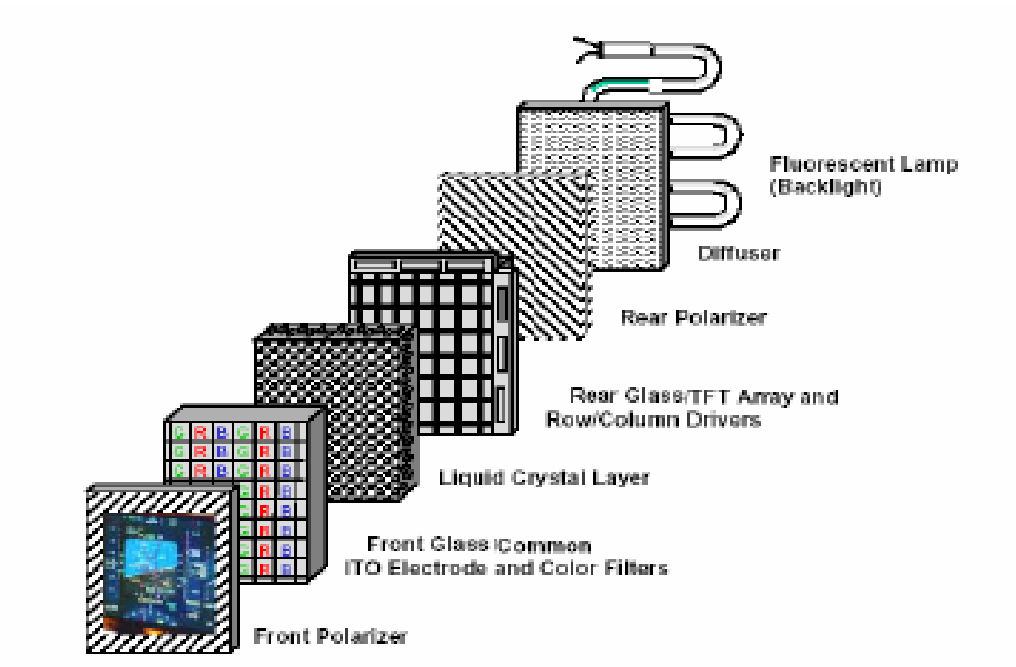


Figure 2.9 LCD structure

Starting from the back side of the LCD panel, the first element is fluorescent lamp which is always on state. The backlight technology assumed as CCFL (Cold Cathode Fluorescent Lamp) but also there are different types and architectures. Because the distribution of light cannot be realized perfectly with limited number of lamps, diffuser is used as the second element to distribute the light to whole display equally and uniformly. After diffuser, light is polarized at rear part in twisted nematic architecture which is the third element. The polarization of light in one direction means passing the half of the light intensity and 50% of the light is absorbed by the polarization filter. Absorption of light while passing through filters decreases efficiency of LCD. TFT arrays are the driving circuitry of the LCD which are matrix structure based on rows and columns. Each pixel is addressed by applying voltage to the gate of the transistor which controls pixel and the required voltage level to control the light output level from addressed pixel is given to the drain of the transistor. Source of the transistor is connected to the metal plates which define the alignment of the liquid crystal material. The alignment of the liquid crystal is controlled by the metal plates which control electric field on liquid crystal. By controlling the alignment of the liquid crystal, output light level can be controlled. As explained above, the fourth layer of the LCD is the TFT arrays used for addressing and it is the driving circuitry of the LCD panel. Liquid crystal layer is the fifth layer. LC material is placed between two planes which are grooved orthogonally for twisted nematic architecture. The electric field between planes is controlled by TFT circuitry which defines the alignment and or shifting angle of the light. Liquid crystal layer defines the output light level by shifting the angle of the polarized light. For normally off panels, which are in structure of ninety degree phase shift twisted nematic liquid crystal, the front polarizer is in the same polarization with the rear polarizer. Assuming both polarizers is horizontally polarized, only horizontally polarized light can pass through the both. However, twisted nematic cell exists between each polarizer which shifts the polarization to ninety degree. Under no electric field, the twisted nematic shifts the polarization from horizontal to vertical and vertical polarized light cannot pass through front polarizer. When electric field applied to TN, the shifting angle increases and horizontally polarized light reaches the front polarizer which also has horizontal polarization and the light is displayed on the screen.

For color displays, color filters in red, green and blue are used. The light coming from the first stage (fluorescent lamp) to color filters is white which includes all colors. Three color filters only pass red, blue and green color for each subpixel. With the combination of these three colors, most of the visible color tones can be displayed on the screen. Unfortunately, LCD technology has lower color range compared with CRT displays because of color filters. Color filters are the sixth layer of LCDs which are used to display color pictures. Seventh layer and the last layer of LCDs is front polarizer which absorbs light in the orthogonal polarization. All filters have huge losses in both density and frequency range of the light. The color filter has the loss factor on the frequency range of the light which means the color loss. The polarizer filter has a huge loss on the light intensity. Because of the current technology for LCD, efficiency and the color range for these panels are limited. The efficiency level is below 30% which means 70% of light is absorbed by the elements on light pass path. Accepting the CRT display color range is 100%, LCD's color range is around 90%. Improvements exist in both areas with new technologies for LCDS.

2.1.3 LCD Driving

Addressing of the pixel is the first step in display driving. Two schemes of addressing is used: direct addressing and matrix addressing.

Direct addressing is used for low resolution displays. Each pixel is directly addressed in this type of addressing. Direct addressing has no usage for TV displays because of resolution limitation. Matrix addressing scheme is used for TV displays. Passive matrix addressing and active matrix addressing are the two types.

The first type of high information density liquid crystal display to become commercially feasible was due to passive matrix technology. It takes its name from the simple design for switching the liquid crystal cells on and off. The individual liquid crystal cells are sandwiched between two sets of electrodes. The electrodes on the bottom layer run at right angles to the ones on the top layer. As a result, activating one row and one column electrode will result in a current running through one specific cell.

The way which a passive matrix creates an image is to activate each electrode row in turn. While a row is selected, column electrodes are activated to turn on only those pixels in that row according to the display data coming from the device using the passive matrix display. When the last row in the display has been scanned, the process starts over from the top. Passive matrix addressing is the simplest and least expensive solution for medium resolution displays.

There are limitations of passive matrix design. If too great a current runs through a cell, then the adjacent cells –often those in the same column- may also be affected and resulting in ghosting. If the current is too weak, the cells don’t switch on or off quickly which reducing the contrast and losing details in moving images. Drawbacks of passive matrix addressing can be summarized as following:

- Current leakage among adjacent pixels causes ghosting, or crosstalk, and reduces sharpness and contrast.
- Because of high twist angles of the liquid crystal, viewing angles are limited.
- Because the slow response time of this architecture, smearing of moving image elements visible.

In the late 1960’s, an alternative to passive addressing was developed which uses a thin film diode in the corner of each LC pixel on the rear backplane of the two glass substrates which make up the LCD sandwich. The thin film diode was later replaced by a thin film transistor. For each pixel, three transistors, which are switching the active elements, are used in active matrix LCD (Sarma, 1999).

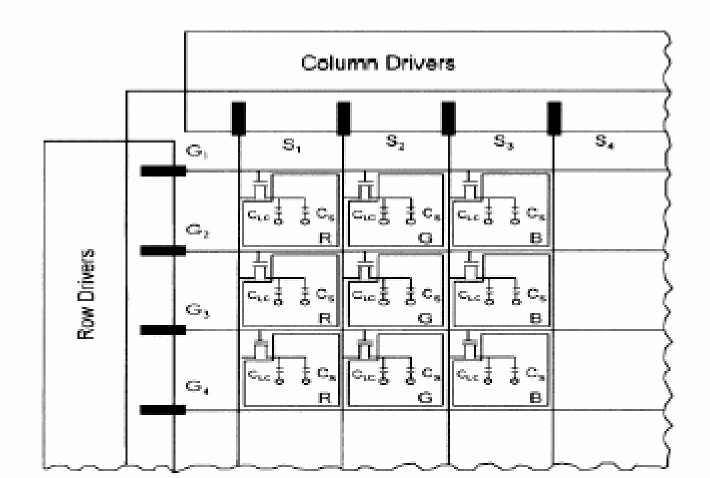


Figure 2.10 Active matrix LCD (Sarma, 1999)

TFT architecture provides more efficiency, although the presence of the opaque TFT within each cell which means that a brighter backlight is required with this addressing method. Current leakage between the top and bottom substrates is reduced because of the isolation provided by the transistor. Moreover, because the transistor controls the charge on the LC material, a conventional twisted nematic alignment can be used reducing smearing and making the display of motion video possible. The finer control also allows a number of variations in LC material and cell configuration to address the problems of ensuring wider viewing angles this method of driving an LC matrix is called active matrix addressing and this type of LCD panels most commonly used.

The structure of the active matrix addressing is given in Figure 2.10. The gates of all transistors in one row are connected together and the voltage according to intended data is applied to the drains of the transistors. If the gate is selected, the applied voltage appears at source of the transistor which drives the electrode plane. The liquid crystal material is between two plates and depending to the dielectric constant of the LC material, a capacitance exists between plates. This capacitance stores voltage level until ext addressing of the row. For better storage of the voltage at one frame interval, additional capacitors are used for each subpixel.

Capacitance between two plates is given in equation 2.1. A is the area and D is the distance between plates and ε_r is the dielectric factor of the material and ε_0 is the dielectric constant of the air.

$$C = \frac{\varepsilon_r \varepsilon_0 A}{D} \tag{2.1}$$

2.1.3.1 LCD Panel Technology

Brief explanation of liquid crystal, operation of LCD, driving circuitry for addressing are described in previous parts. This part is dedicated to the structural details, operational details and different technologies developed for LCD panels.

Structural view at side cut and front cut of LCD panel are shown in Figure 2.11 and 2.12. Liquid crystal is located between two plates and spacer is used for physical space generation for LC material. Figure 2.11 is for twisted nematic architecture. LC material is located between plates and they are in twisted alignment. As mentioned before, each pixel is formed by R, G, B subpixels and each subpixel is controlled by a transistor. Three times the panel resolution of transistors exist for control circuitry and same number of subpixels exist at color filter as shown in Figure 2.12.

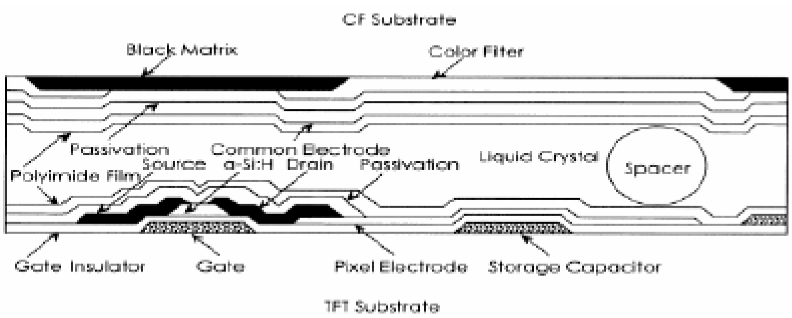


Figure 2.11 Structurel view at side cut of LCD panel (Morris, 1993)

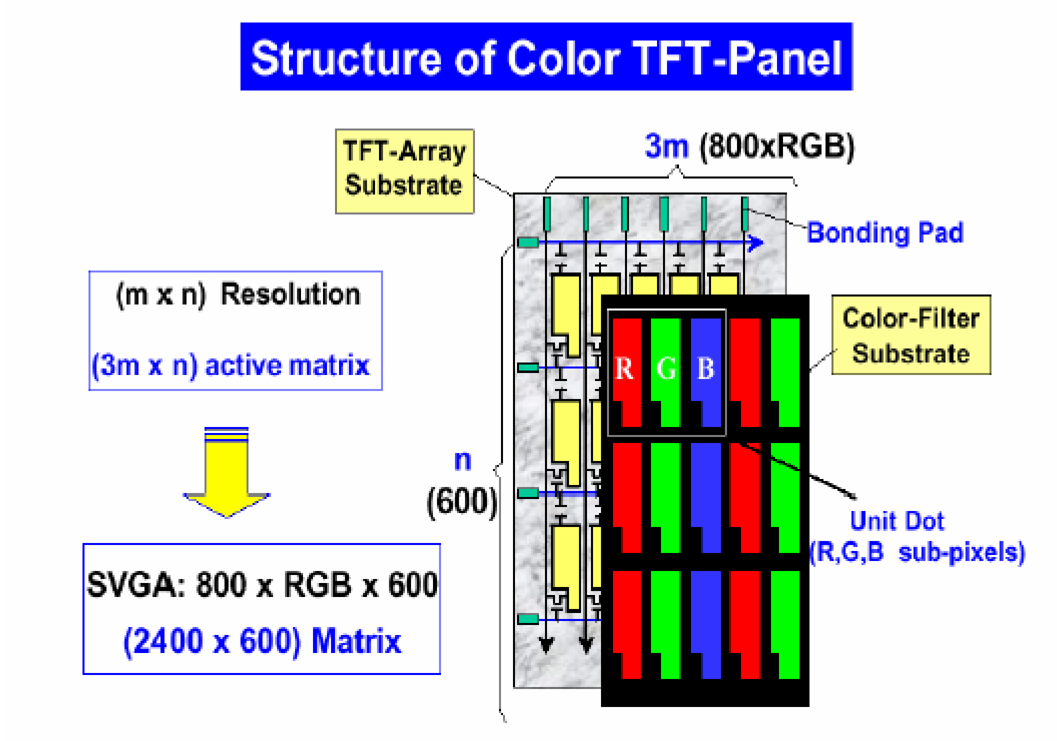


Figure 2.12 Structural view at front cut of a VGA resolution LCD panel (Morris, 1993)

2.2 Backlight Technology

TFT-LCD panels use two types of backlight technology: cold cathode fluorescent lamp and LED backlight.

2.2.1 Cold Cathode Fluorescent Lamp (CCFL)

CCFL is the current technology used commonly for LCD panels. The location of CCFLs and the number of lamps in one panel depends to the panel size and the manufacturer. Uniformity is the important parameter for backlight. So CCFL panels use diffuser for improving the uniformity of light on the screen. Without the diffuser, uniformity is limited because the number of lamps is limited physically.

Power driving circuitry of lamps is called as inverter. The performance of CCFL backlight technology depends on the driving circuitry and structure. If the lamps are located parallel in horizontal direction, one side is grounded and the lamps are driven from the other side, the light level at the grounded side is generally lower than the other side. This decreases uniformity. The alternative driving circuitry is applying positive voltage to one and negative voltage to other side of the lamp which improves uniformity the backlight.

Because of physical and electrical limitations, CCFL technology has limited performance but it is the common technology used in LCD panels currently.

2.2.2 LED Backlight

LED backlight technology will take the role of CCFL technology, but the current stage is expensive and needs to be validated. Several LEDS are placed at the backside of the LCD panel and light is generated by these elements. The advantage of this technology is increasing uniformity. Since the number of lighting point is fifty times more than CCFL technology (CMO, 2006).

Special video enhancement algorithms are also used to drive LEDs. Most common algorithms used in LED backlight technology for contrast enhancement. LEDs are controlled individually and the brightness of LEDs at the dark side of the picture is decreased to black level.

CHAPTER THREE

ELECTROMAGNETIC COMPATIBILITY (EMC)

Electromagnetic compatibility (EMC) is the capability of electrical and electronic systems, equipment and devices to operate in their intended electromagnetic environment within a defined margin o f safety without suffering or causing unacceptable degradation as a result of electromagnetic interference (ANSI-C64.14, 1992).

In other words, electromagnetic compatibility can be defined as the ability of different pieces of electrically operated equipment to work in close proximity to each other without causing any mutual interference. EMC therefore implies the ability of equipment to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbance to any other equipment in that environment. Therefore, EMC is a twofold occurrence consists of emission and immunity:

1. Electromagnetic emission: It is the phenomenon by which electromagnetic energy emanates from a source.

2. Electromagnetic immunity: It is the ability of a device, equipment or system to perform without degradation in the presence of electromagnetic disturbances. Electromagnetic susceptibility is the inability of the device to perform without degradation, i.e. susceptibility is the lack of immunity.

3.1 The Need for EMC

Electrical and electronic products often (unexpectedly) produce radio frequency (RF) energy. Every digital device has the potential of causing unintentional interference to other electrical devices. Electrical devices are used in every aspect of our lives, such as providing communication, entertainment, life support and etc.

Control of electromagnetic compatibility (EMC) is an increasing necessity because significant improvement has been made in electronics technology. The variety and number of devices using microprocessor controlled circuits have increased dramatically and have led to the widespread usage of digital circuits using very low signal levels (currents) in domestic appliance, audio-video equipment and so on. These devices when exposed to high level of electromagnetic field strength can be prone to malfunction. Also, digital working circuits are a source for electromagnetic emission.

3.1.1 Organizations

There are three international organizations that determine EMC standards. These organizations are:

IEC: International Electrotechnical Committe
CISPR: Comite International Special des Perturbations Radio Electriques
CENELEC: Comite Europeen de Normalisation Electrotechnique

The standards prepared by these organizations and technical stuff are named differently. Table 3.1 gives the names of the standards for these organizations.

Table 3.1. IEC, CISPR and CENELEC standards

Cenelec Standards	EN 50 XXX	e.g. 50 081
CISPR Standards	EN 55 XXX	e.g. 55 013
IEC Standards	EN 60 XXX	e.g. 60 555

These standards are accepted international standards and electrical devices are audited according to them. European Union started regulations about in 1992 and became obligatory in 1996. Every electrical device has to comply with these standards to carry CE (Conformity Europe) marking to enter European market. This means that these devices are guaranteed to satisfy the conditions denoted in related standards.

The first act for EMC is published in 1934 by US Congress due to interference to communication systems in North America. The Federal Communications Commission (FCC) was created to oversee enforcement and administration of this act. Electromagnetic interference was also a problem during World War II and this phenomenon is called Radio Frequency Interference (RFI). Conferences on EMI began to be held in the mid 1950s where unclassified information was presented. As logical devices were increasingly developed for consumer systems, EMI became a wider concern. In the late 1970s, problems associated with EMC became an issue for the products including home entertainment systems (TVs, VCRs,..), PCs, communication equipment, household appliances with digital features, control systems, audio and video displays and numerous other applications. During this period, the public became aware of EMC and problems associated with it. After the public became involved in EMI associated with digital equipment used within residential areas, FCC in the late 1970s began to promulgate an emission standard for personal computers and similar equipment. (Montrose&Nakauchi, 2004)

The EMC Directive 89/306/EEC, adopted in 1983, amended in 1992 and mandated from January 1, 1996, is one of the most complexes of EU New Approach Directives. It affects all sectors of industry which supply electrical and electronic apparatus to the EU. This directive applies to apparatus liable to cause electromagnetic disturbance or the performance of which is liable to be affected by such disturbance. The purpose of this paper is to render a little more understanding to the phenomenon of EMC and to provide some practical guidelines and techniques to bring equipment into compliance with the EMC directive. (Isakov, n.d.)

3.2 Definitions Related With EMC

- Electromagnetic Interference: Electromagnetic interference (EMI) is the process by which disruptive electromagnetic (EM) energy is transmitted from one electronic device to another via radiated or conducted paths or both. In common usage, the term refers particularly to RF signals; however, EMI is observed throughout the EM spectrum.

- Radio Frequency: A frequency range containing coherent EM radiation of energy useful for communication purposes, roughly the range from 9kHz to 300GHz. This energy may be emitted as a result of electronic device's operation. Radio frequency is emitted through two basic mechanisms:

1. Radiated Emission: The component of RF energy that is emitted through a medium as an EM field. Although RF energy is usually emitted through free space, other modes of field transmission may be present.

2. Conducted Emission: The component of RF energy that is emitted through a medium as a propagating wave, generally through a wire or interconnect cables. Line conducted interference (LCI) refers to RF energy in a power cord or alternating current (AC) mains input cable. Conducted signals propagate as conducted waves.

- Susceptibility: A relative measurement of a device or a system's propensity to be disrupted or damaged by EMI exposure to an incident field. It is the lack of immunity.

- Immunity: A relative measure of a device or a system's ability to withstand EMI exposure while maintaining a predefined performance level.

1. Radiated Immunity: A product's relative ability to withstand EM energy that arrives via free space propagation.

2. Conducted Immunity: A product's relative ability to withstand EM energy that penetrates through external cables, power cords and input/output (I/O) interconnects.

- Suppression: The process of reducing and eliminating RF energy that exists without relying on a secondary method, such as a metal housing or chassis. Suppression may include shielding and filtering as well.

3.3 Electromagnetic Interference (EMI)

Electromagnetic interference can be described as the degradation of a device or system caused by an electromagnetic disturbance. An electromagnetic disturbance is any electromagnetic phenomenon which may degrade the performance of a device, equipment or system. Therefore an electromagnetic disturbance can be an unwanted signal or even a change in the propagation medium itself. A change in the propagation medium can attenuate the signal and have a direct effect on the level of disturbance.

Electromagnetic environment can be described as the electromagnetic conditions existing at a given location. The EMI environment includes interference emanating from natural sources to various manmade sources.

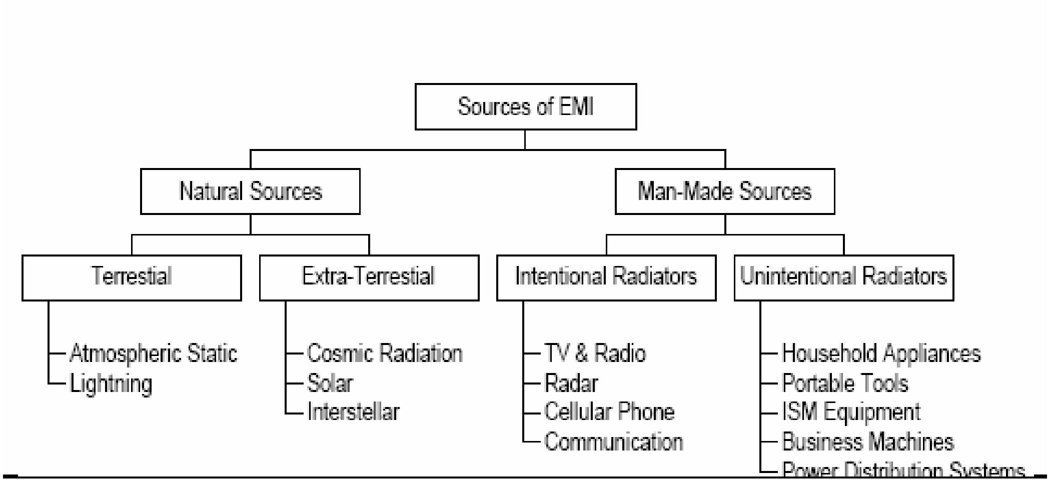


Figure 3.1 Electromagnetic Interference Sources (Isakov, n.d.)

There is very little that can be done to prevent the interference from natural sources. However, natural sources do not create that much of a problem. It is also difficult to prevent EMI from intentional sources of electromagnetic energy. However the major source of all interference is generated from unintentional manmade sources. This is due to vast amount of electrical and electronic equipment in use.

There are three essential elements to any EMC problem. There must be an EMI source or an electromagnetic disturbance, a receptor or victim that cannot function properly due to the electromagnetic phenomenon, and a path between them that allows the source to interfere with the receptor. This is shown in Figure 3.2. Each of these three elements must be present at the same time to cause EMI.

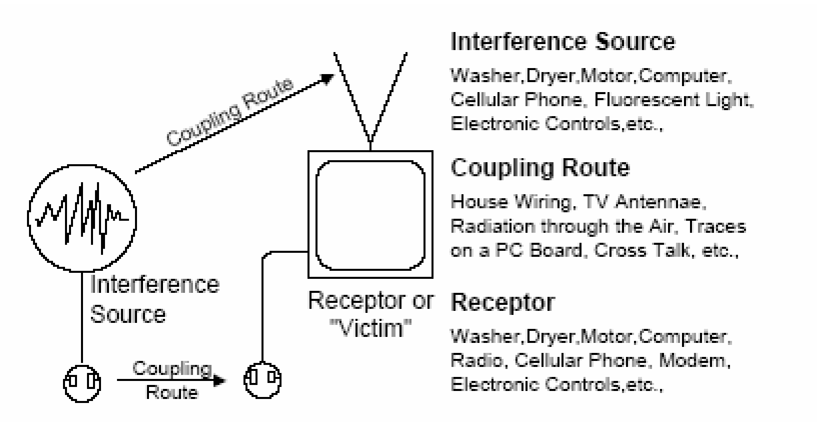


Figure 3.2 Three sources of EMI problem (Isakov, n.d.)

3.3.1 Methods of Noise Coupling

As said before, a product must be designed for two levels of performance; one is to minimize RF energy exiting from the enclosure (emission), and the other is to minimize RF energy entering the enclosure (susceptibility or immunity). Both emissions and immunity travel by either radiated or conducted paths. This relation is shown in Figure 3.3.

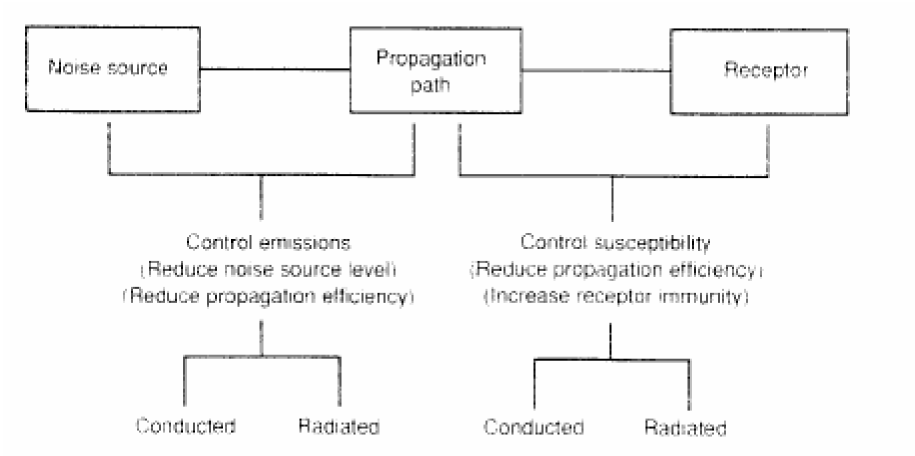


Figure 3.3 Coupling paths (Montrose, 1998)

To further examine the coupling paths, it must be realized that the propagation path contains multiple transfer mechanisms. These are detailed in Figure 3.4.

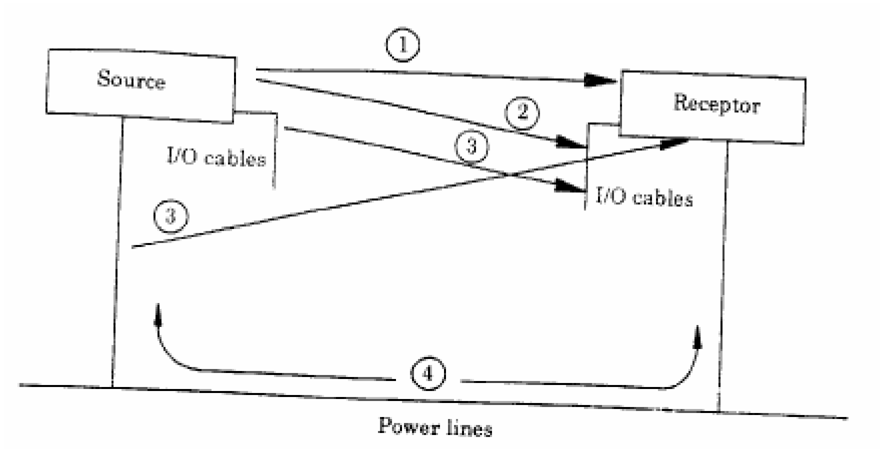


Figure 3.4 Coupling path mechanism (Montrose, 1998)

The paths are explained below in detail:

Path 1: Direct radiation from source to receptor.

Path 2: Direct RF energy radiated from the source is transferred to AC mains cable or signal/control cables of the receptor.

Path 3: RF energy radiated by AC mains, signal or control cables from source to receptor.

Path 4: RF energy conducted by common electrical power supply lines or by common signal /control cables.

Generally multiple paths of coupling exist in an EMI problem. In this thesis, the EMI problem is caused by the coupling through the second path in Figure 3.4. The source might be any electrical device where victim is a TFT television. The work done in this thesis is to increase the immunity of the TV set to the coupling through its antenna cable.

3.4 CISPR 20

CISPR 20 is the standard that determines the sound and television broadcast receivers and associated equipment immunity characteristics, limits and methods of measurement. The standard is defined by IEC.

This standard for immunity requirements applies to the television broadcast receivers, sound receivers and associated equipment intended for use in the residential and light industrial equipment. (CISPR 20, IEC-2006). The standard describes the methods of measurement and specified limits applicable to sound and television receivers and to associated equipment with regard to their immunity characteristics to disturbing signals.

The objective of this standard is to define the immunity test requirements for equipment defined in the scope in relation to continuous and transient conducted and radiated disturbances including electrostatic discharges. In this thesis, only the immunity to RF voltages at antenna terminal will be considered.

The test requirements represent essential electromagnetic immunity requirements. Test requirements are specified for each port considered.

The environments encompassed by this standard are residential, commercial and light industrial locations, both indoor and outdoor. Locations which are characterized by their mains power being supplied directly at low voltage from the public mains are considered to be residential or light industrial.

3.4.1 Terms, Definitions and Abbreviations

- Television Receiver: Appliances intended for the reception of television broadcast and similar services for terrestrial, cable and satellite transmissions. These TV receivers can be digital receivers with digital incoming data signals or receivers with digital processing of digital or analogue incoming signals.

- Disturbance Signal: An unwanted signal which may degrade radio reception or cause malfunction in equipment , specific unwanted signals are simulating disturbance signals, generated under laboratory conditions.

- Immunity: Ability to maintain a specified performance when the equipment is subjected to disturbance (unwanted) signals of specified levels. In this standard, the specified performance is

a.) a specified sound signal to interference ratio
b.) no greater than just perceptible degradation of the picture when a wanted signal and an unwanted signal occur simultaneously.

- Input Immunity: Immunity from unwanted signal voltages present at the antenna input terminal.

- Immunity from Conducted Voltages: Immunity from unwanted signal voltages present at he equipment terminals for audio and mains input and audio input.

- Immunity from Conducted Currents: Immunity from unwanted signal (common mode) currents present in cables connected to the equipment.

- Immunity from Radiated Fields: Immunity from unwanted electromagnetic fields present at the equipment.

- Screening Effectiveness: Characteristics of a coaxial connector terminal to attenuate the transfer of internal voltages into external fields and vice versa.

- Port: Particular interface of the specified apparatus with the external electromagnetic environment

- Enclosure Port: Physical boundary of the apparatus through which electromagnetic fields may radiate or impinge.

- AM: Amplitude Modulation

- EUT: Equipment Under Test

- Emf: electromotive force

- FM: Frequency Modulation

- RF: Radio frequency

3.4.2 Immunity Requirements

3.4.2.1 Evaluation of Audio Quality

The criterion of compliance with the requirement is a wanted to unwanted audio signal ratio (SN) of >40dB at a wanted audio signal level of 50mW. If SN ratio is less than 43dB, the performance criterion for audio assessment is the actual SN ratio minus 3dB. In this case, at the beginning of the audio quality evaluation the actual SN ratio is measured and noted in the test report as a reference value. (CISPR 20, 2006)

3.4.2.2 Evaluation of Picture Quality

In the evaluation of picture interference, the wanted test signal produces a standard picture and the unwanted signal produces a degradation of the picture. The degradation may be in a number of forms, such as a superposed pattern, disturbance of synchronization, geometrical distortion, loss of picture, contrast, color and etc.

The criterion of compliance with the requirement is just perceptible degradation by observation of the picture. The screen shall be observed under normal viewing conditions at a viewing distance of six times the height of the screen. (CISPR 20, 2006)

3.4.3 Performance Criteria

3.4.3.1 Performance Criteria A

The equipment shall continue to operate as intended during the test. No change of actual operating state (for example change of channel) is allowed as a result of the application of the test. Evaluation is carried out for audio and video functions. The equipment is supposed to operate as intended if the criteria denoted in 3.4.2.1 and/or 3.4.2.2 are fulfilled. (CISPR 20, 2006)

3.4.3.2 Performance Criteria B

The equipment shall continue to operate as intended after the test. No loss of function is allowed after the test when the apparatus is used as intended, but failures which are recovered automatically but which cause temporary delay in processing, are permissible. No change of actual operating state for example change of channel or stored data and settings is allowed as a result of the application of the test. During the test, degradation of performance is allowed. (CISPR 20, 2006)

3.4.3.3 Requirements for Immunity RF Voltages (Common Mode) at Antenna Terminal

The requirements for receivers, multifunction equipment and video type equipment concerning the immunity to RF voltages in common mode are restricted to the antenna terminals and to the frequency range from 26kHz to 30MHz. requirements are applied to equipment operating in receiving mode. Receivers and multifunction equipment shall meet the sound criterion in 3.4.2.1 and picture criterion 3.4.2.2 as appropriate for unwanted signals of frequencies as specified in Table 3.2.

Table 3.2. Limits of immunity to RF voltages of antenna terminals (CISPR20, 2006)

Frequency MHz	Level dB(µV) (e.m.f.)
26 to 30	126
NOTE 1 For system L the test level in the frequency range 28 MHz to 30 MHz is 116 dB(µV) (e.m.f.). NOTE 2 According to the measuring procedure the immunity from conducted current is expressed by the e.m.f. level of the unwanted signal generator (Figures 5 and 6).	

3.4.4 Performance Assessment

3.4.4.1 Measurement Procedure for Audio Assessment

First the wanted test signal is applied to the equipment under test. This produces a wanted audio signal which is measured. The volume control of the equipment under test is adjusted to set the audio signal at the required level which is 50mV. Then the wanted signal is removed by switching off the modulation or the audio test signal.

The unwanted disturbance signal is applied in addition and its frequency is swept through the test range; its level is kept at the relevant limit value.

The evaluation of the interference is made by measuring the level of the unwanted output signal and comparing this to the wanted output level.

Audio output power is measured at the external loudspeaker terminals across the load impedance. The wanted and unwanted audio signals are measured.

3.4.4.2 Measurement Procedure for Video Assessment

The standard picture is a pattern consisting of vertical color bars an accordance ITU-RBT.471-1.

First the wanted signal only is applied to the equipment under test. The controls of the equipment under the test are set to obtain a picture of normal brightness, contrast and color saturation.

The unwanted signal is applied in addition, its frequency adjusted to the relevant values. The level of the unwanted signal shall be maintained at the relevant limit value at each frequency. The EUT is considered to meet the requirement if the picture quality evaluation is fulfilled.

3.4.5 Measurement of Immunity to RF Voltages (Common Mode) at Antenna Terminal (S2C)

The general principle of measurement is illustrated in Figure 3.5

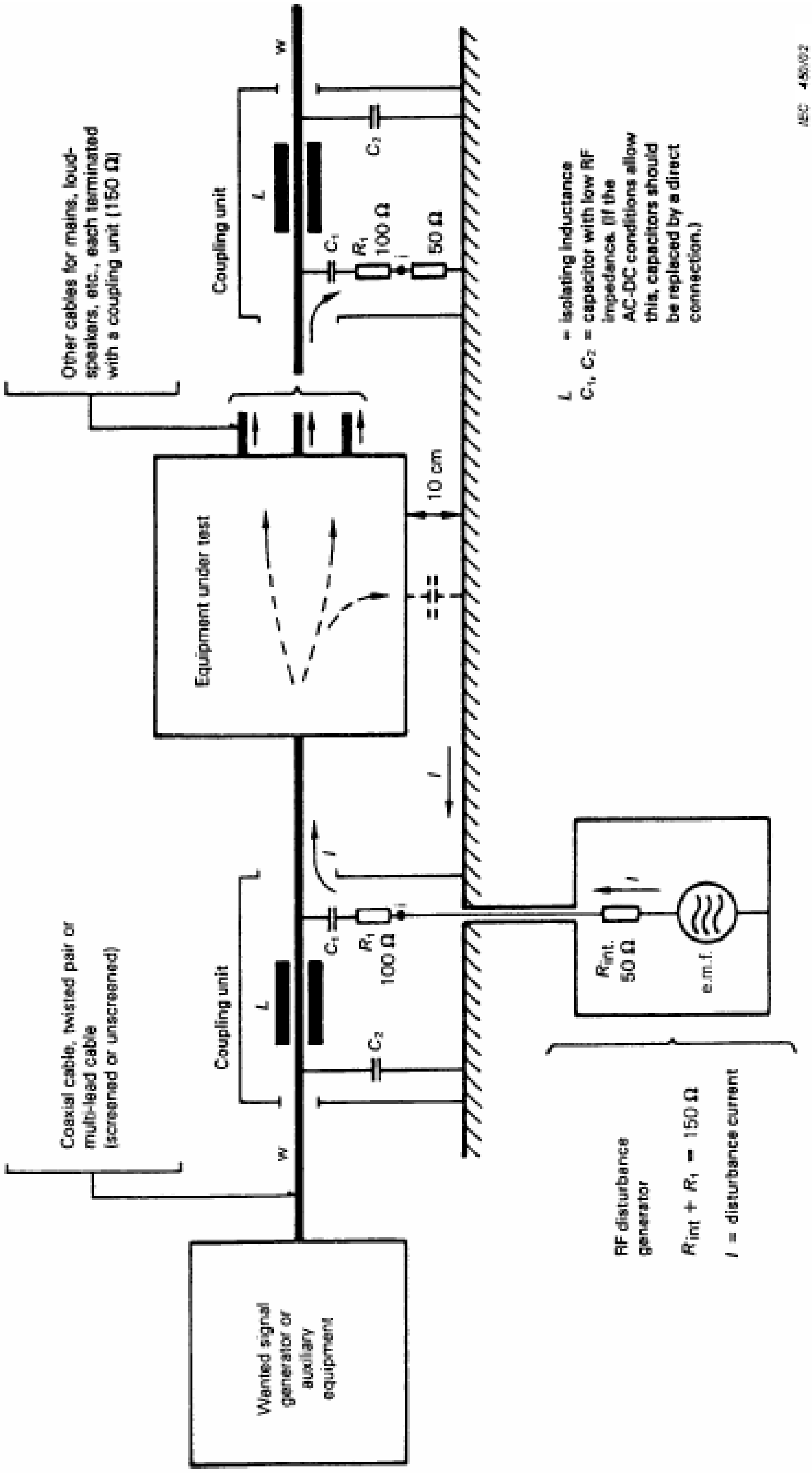


Figure 3.5 General principle of the current injection method (CISPR 20, 2006)

The effects of interference signals induced onto a lead of equipment in an actual situation are simulated by the injection of an unwanted signal to current on the lead through a suitable coupling unit. This test simulates induced current on an antenna cable and the effect of this current running from antenna ground to the board ground. In the case of unshielded leads, the unwanted current is injected in common mode onto the conductors. In the case of coaxial or shielded cables, the unwanted current is injected onto the outer conductor or the shield of the cable. The current flows through the earth capacitance of the equipment under the test and through the load impedances of the other terminals provided by coupling units.

3.4.5.1 Coupling Units

The coupling units contain RF chokes and resistive networks for the injection of unwanted currents. The impedance of the unwanted signal voltage source and the load impedances are standardized at 150Ω and the coupling units are designed to provide this impedance. They also permit the passage of the wanted test signal, other signals and mains supply. (CISPR 20, 2006)

Four types of coupling units have been found to be required to provide for frequency, connector and cable variations. The types of the coupling units and their usages are summarized below:

Type AC: For use with coaxial cables carrying wanted RF signals. The construction details are shown in Appendix A Figure A.1.

Type MC: For use with mains lead. The construction details are shown in Appendix A Figure A.2.

Type LC: For use with loudspeaker leads. The constructional details are shown in Appendix A Figure A.3.

Type Sr: For use where there is no requirement to provide a through path for a wanted signal. All leads of the cable are terminated with a matched load resistance. The construction details are shown in Appendix A Figure A.4.

3.4.5.2 Measurement Setup

The measurement setup is shown in Figure 3.6.

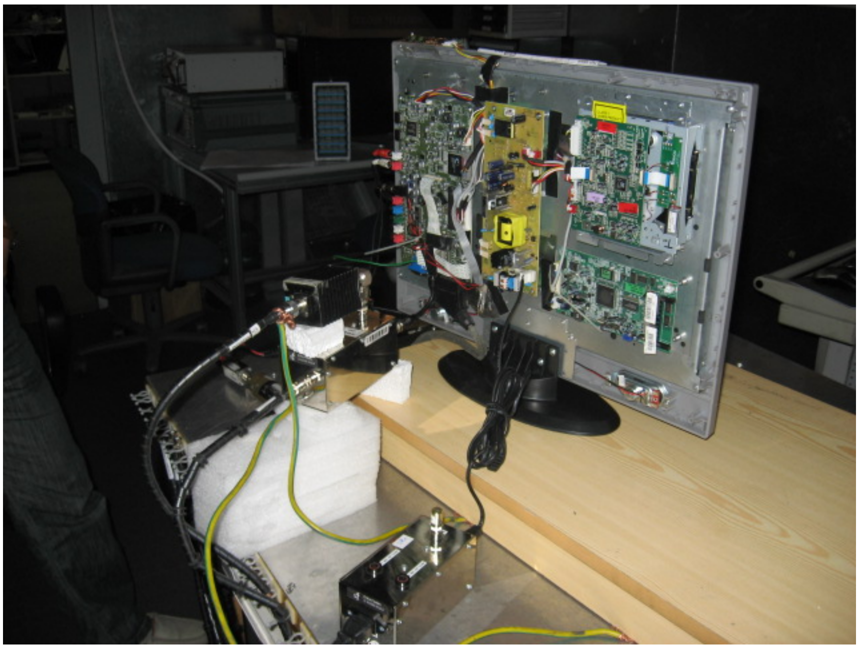
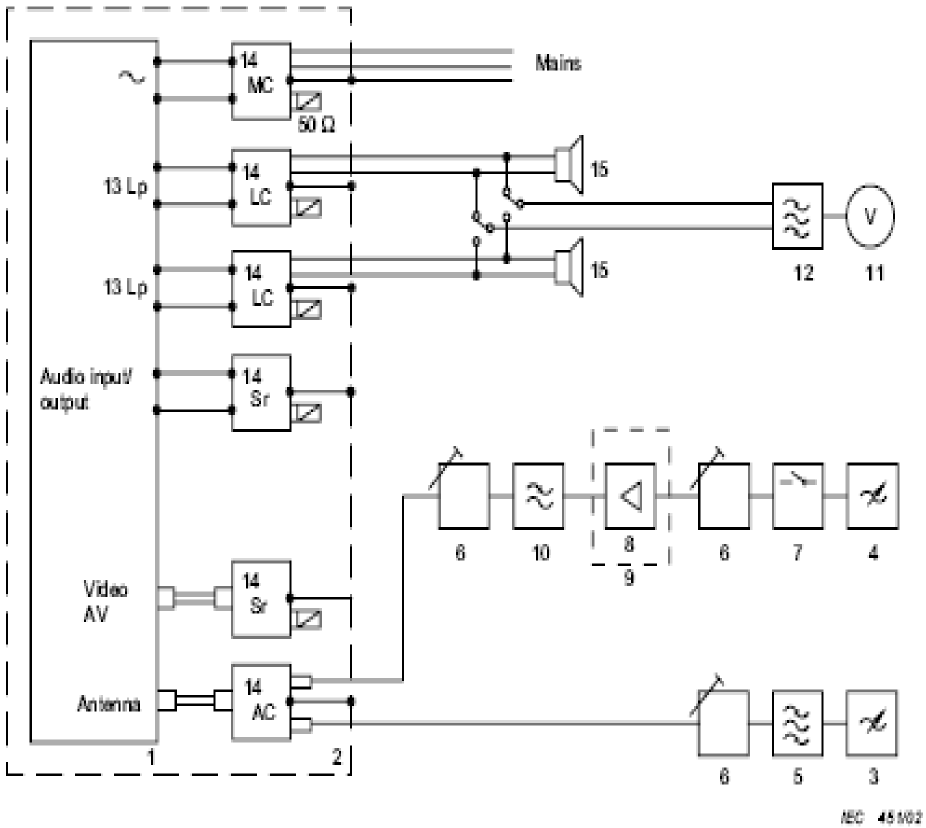


Figure 3.6 Measurement setup for S2C

The equipment under test is placed 0,1m above a metallic ground plane of dimensions 2m by 1m. The coupling units are inserted into the various cables respectively. The cables linking the coupling units to the equipment under test shall as short as possible. The mains lead shall be bundled to give a length of less than 0.3m. A coupling unit shall be At least one port of each type of terminal shall be used.

3.4.5.3 Measurement Circuit

The measurement circuit is given in Figure 3.7.



Key

1 Equipment under test
2 Metal plate P = 2 m × 1 m
3 Generator of wanted signal G1
4 Generator of unwanted signal G2
5 Channel filter Fc
6 Attenuators T1, T2, T3
7 Switch S1
8 Amplifier Am
9 Shielded box Sh
10 Low-pass filter F
11 Audio frequency voltmeter V
12 Band-pass filter 0,5 kHz to 3 kHz (see Annex B)
13 Loudspeaker connectors Lp
14 Coupling units MC, LC, Sr, AC (see Annex C) of the loudspeaker
15 Dummy load simulating the nominal impedance of the loudspeaker

Figure 3.7 Measurement principle for the immunity from conducted currents (S2C)

The wanted television signal including the sound part is supplied by generator G1, followed by a channel filter Fc and an attenuator T3. The role of the attenuator is

- To avoid reflections to the source
- 6dB attenuation of the signal
- 50Ω output since there is a 50-150Ω converter in the next step.

The unwanted signal is supplied by the generator G2 followed by a switch S1, an attenuator T1, a wideband amplifier Am, a lowpass filter F and an attenuator T2. The switch is used to remove the unwanted signal from the system during the test for checking the noise on the screen. The wideband amplifier Am is used to increase the signal level since the output of the signal generator G2 is not enough for tests. The shield is used to avoid direct radiation. The purpose of the lowpass filter F is to attenuate the harmonics of the unwanted signal source. The frequency response of the filter F shall have a sharp cutoff at a frequency of a few megahertz below the frequency band to be protected (IF and reception band) and shall have a high attenuation in this frequency band. The lowpass filter characteristics is shown in Figure 3.8.

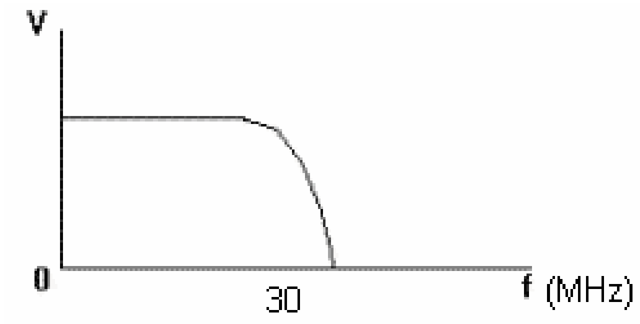


Figure 3.8 Lowpass filter characteristic

The attenuator T2 (6dB to 10dB) provides a matched 50Ω load to the power amplifier output and defines the source impedance. Ground terminals of EUT shall be connected to the ground plane through a 150Ω resistor.

The real setup used thesis work is shown in Figure 3.9 and Figure 3.10.

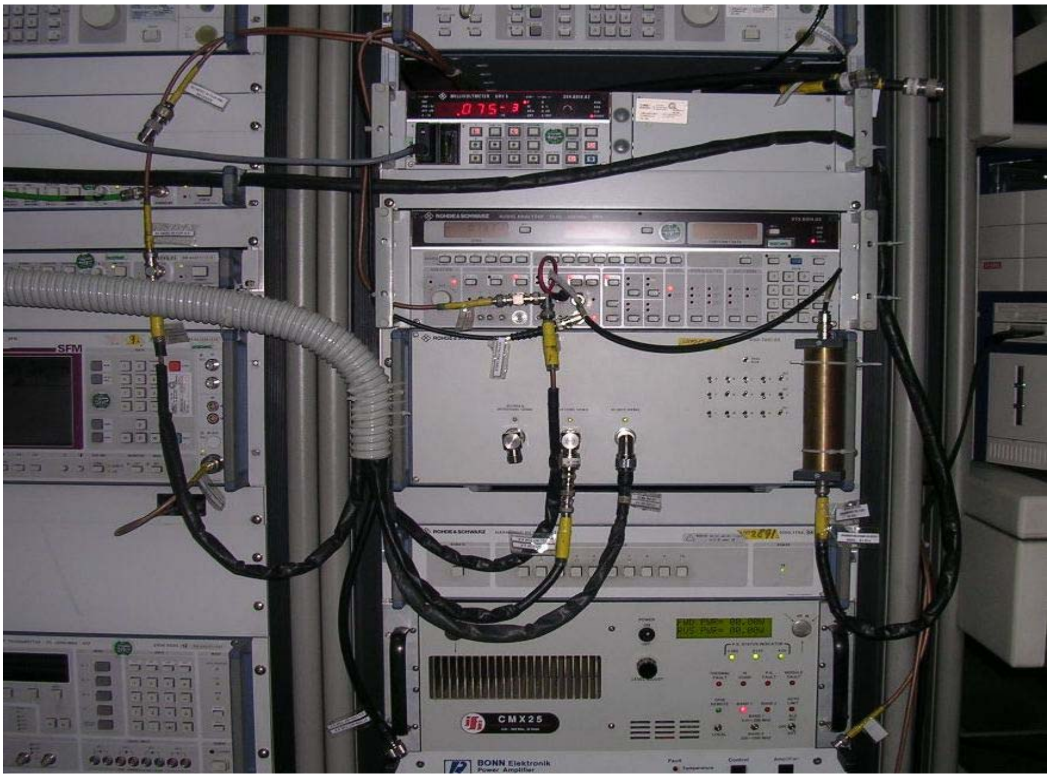


Figure 3.9 Signal generators

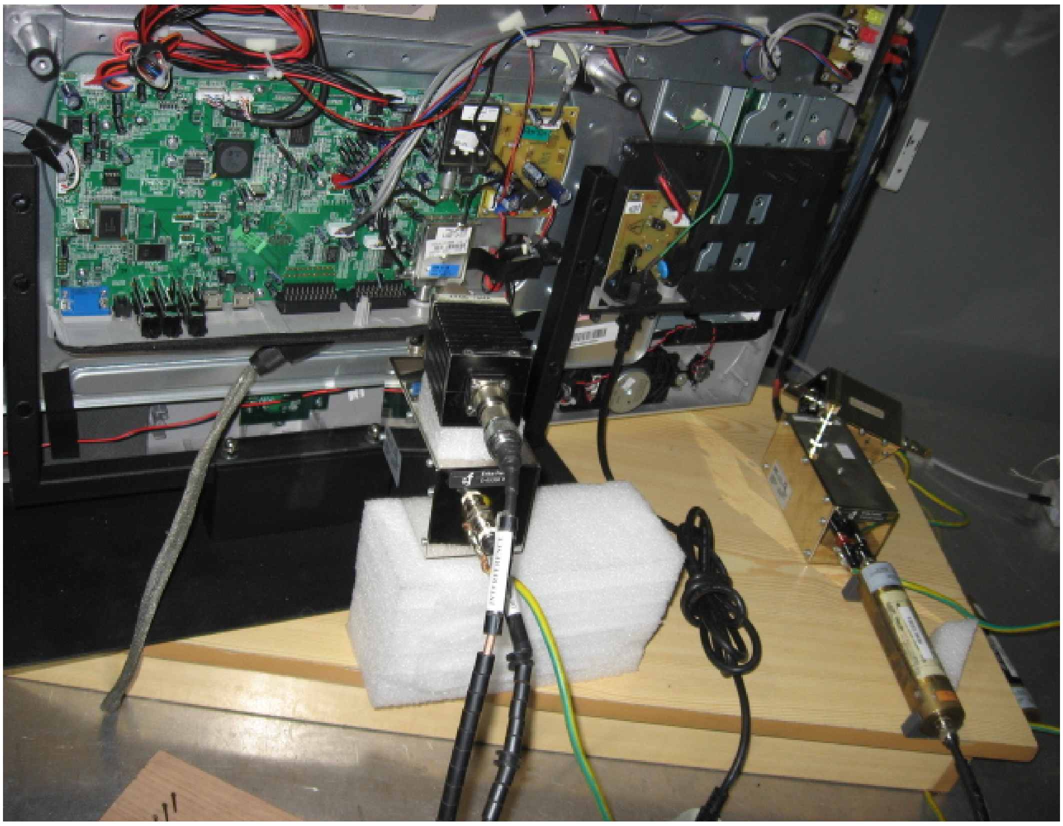


Figure 3.10 EUT and coupling units for S2C test

3.4.5.3 Measurement Procedure

The wanted television signal shall be at a picture carrier level of 70dB (μV) referred to 75Ω modulated with a vertical color bar pattern

- At the picture carrier frequency of the middle channel of the lowest band available in the EUT B, G, I, D, K, M as appropriate;
- At the picture carrier frequency in the lowest of the channels 04, 08, 25, 55 available in the EUT for system L as appropriate.

For systems B, G, I, D, K the sound carrier is frequency modulated with a 1 kHz at a frequency deviation of 30 kHz.

For system L, the sound carrier is amplitude modulated with 1 kHz at 54% depth.

The sound carrier level is 70-x dB (μV) where x=13 for systems B and G and x=10 for systems I, L and D, K.

The unwanted signal is amplitude modulated at 1 kHz 80% depth as shown in Figure 3.11. (CISPR 20, 2006)

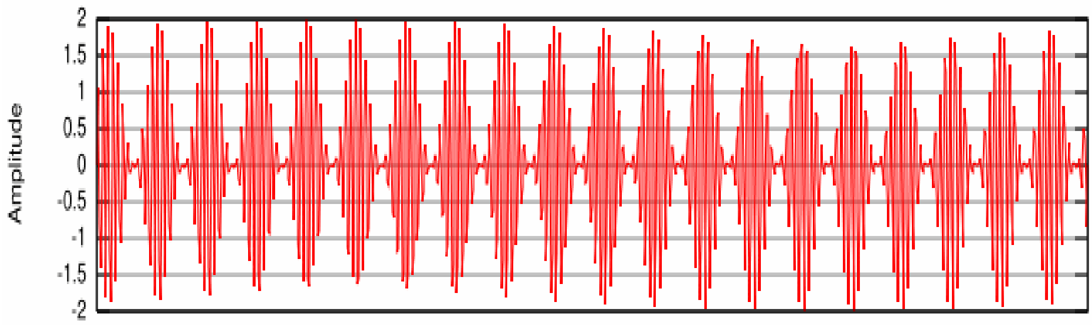


Figure 3.11 The unwanted signal

CHAPTER FOUR

LCD DRIVER BOARD DESIGN

In this chapter of the thesis, the design and general blocks of the TFT TV driver board, which EMC work applied in the next chapter, will be explained. The board is called 17mb26. It can receive and decode analogue broadcast by itself and digital broadcast with the help of some module cards. It also has both digital and analogue video and audio interface. The output of the board to the panel is LVDS (low voltage differential signal) and analogue audio signal to audio interfaces.

The target specifications for the board are that the board must support:

- Analog and digital RF reception
- PC, YPbPr, scart, FAV analogue inputs
- HDMI digital input
- FHD panel support
- PIP/PAP (Picture In Picture/Picture And Picture) features

Through these requirements, the design starts with a general block diagram as shown in Figure 4.1.

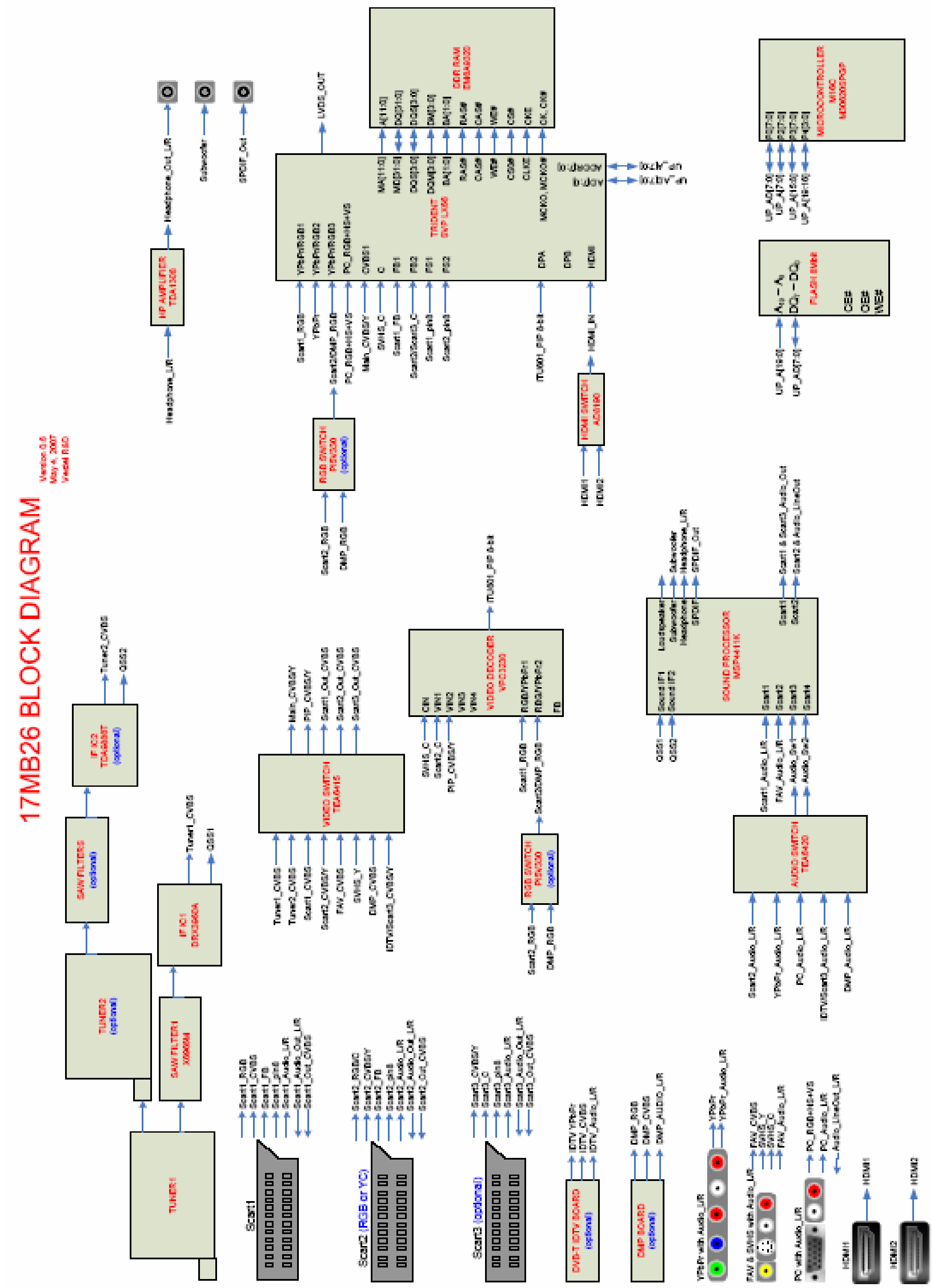


Figure 4.1 General block diagram of the FPD driver board

4.1 The Blocks of the Board

The function of each block will be explained in detail in the following part.

4.1.1 Tuner

Tuner is the basic front end block for RF reception. TV broadband RF signals are placed between 50MHz to 850MHz in the frequency spectrum. The channels including audio and video information are modulated to frequencies in this band are down converted intermediate frequency around 38Mhz by the tuner. Tuner internal structure block diagram is shown in Figure 4.2.

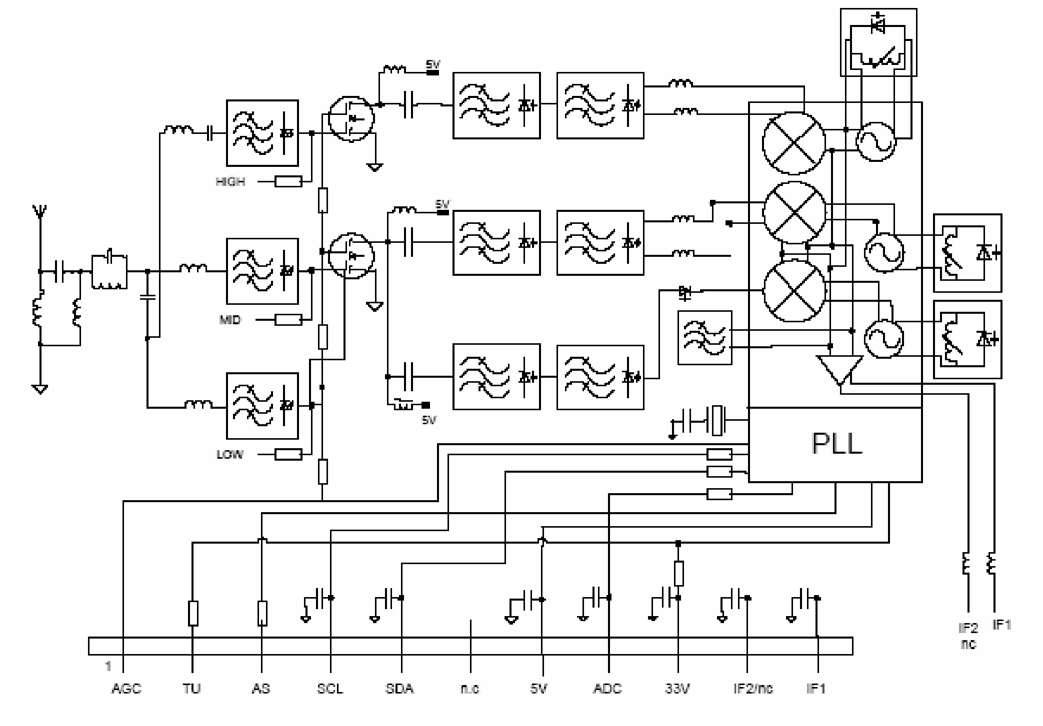


Figure 4.2 Tuner internal structure (Philips, 2004)

The tuner includes three bandpass filters for high, mid and low frequency selection. After channel selection a preamplifier is used to improve SNR. Filtered and preamplified signal is down converted to intermediate frequency (IF) by the mixers. The output of the tuner is IF signal and goes to SAW filter.

4.1.2 SAW Filter

SAW (Surface Wave Acoustic) filter is an electromechanical bandpass filter. SAW filters include piezoelectric material, not electrical components such as inductor or capacitor. Electrical signals are converted to mechanical waves and then converted back to electrical signals. The reason of using SAW filter is their sharp transition at the cutoff region. Thus, the effects of neighbor channels are eliminated better. The equivalent bandpass filter of a SAW filter must have a very high order which is difficult to realize with discrete components. The SAW filter frequency characteristic is shown in Figure 4.3.

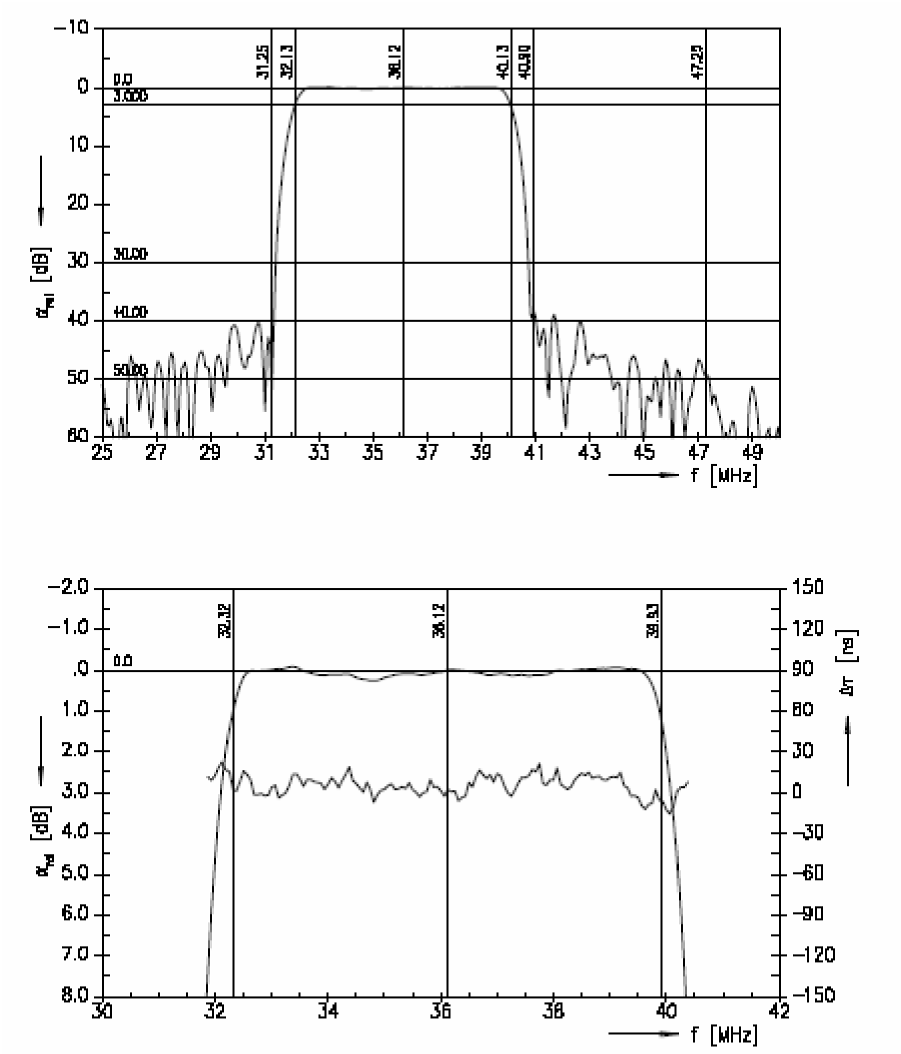


Figure 4.3 SAW filter frequency characteristics (Epcos, 2001)

Since the IF demodulator used in the project is able to separate video and audio carriers by itself, only one SAW filter –EPCOS X9666- is used whose bandpass includes both video and audio carrier frequencies. Otherwise two SAW filters with different passbands for audio and video carrier must be used.

4.1.4 IF Demodulator

The role of the IF demodulator is to convert the IF signal to baseband video signal (CVBS) and QSS (Quasi Split Sound) modulated audio signal. QSS can be AM or FM modulated audio signal. DRX 3960A is the main IF demodulator used in the project. The internal block diagram of the demodulator is shown in Figure 4.4.

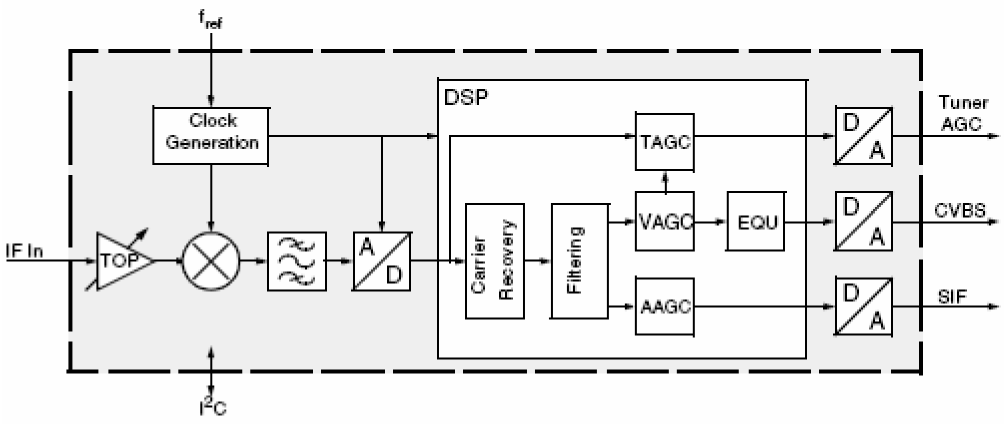


Figure 4.4 Internal block diagram of IF demodulator (Micronas, 2004)

The processing steps within DRX3960A are summarized below:

- Analog down mixing to IF
- Adjacent channel suppression
- Analog to digital conversion
- Carrier locking including AFC information
- Nyquist slope adjustment
- Video-sound splitting
- Video AGC, including delayed tuner AGC

- Group delay equalization
- Video and sound frequency shaping
- Video demodulation
- SIF generation and AGC

After these steps, the demodulated CVBS and the sound IF (SIF) are available as analogue output signals.

4.1.5 Audio Processor

The sound processor IC used in the project is MSP4411K. The input to the audio processor is the sound IF coming from the IF demodulator, analogue audio inputs from scart, YPbPr, PC, side AV interfaces and digital I2S signal from HDMI. The internal blocks of the MSP4411K is shown in Figure 4.5.

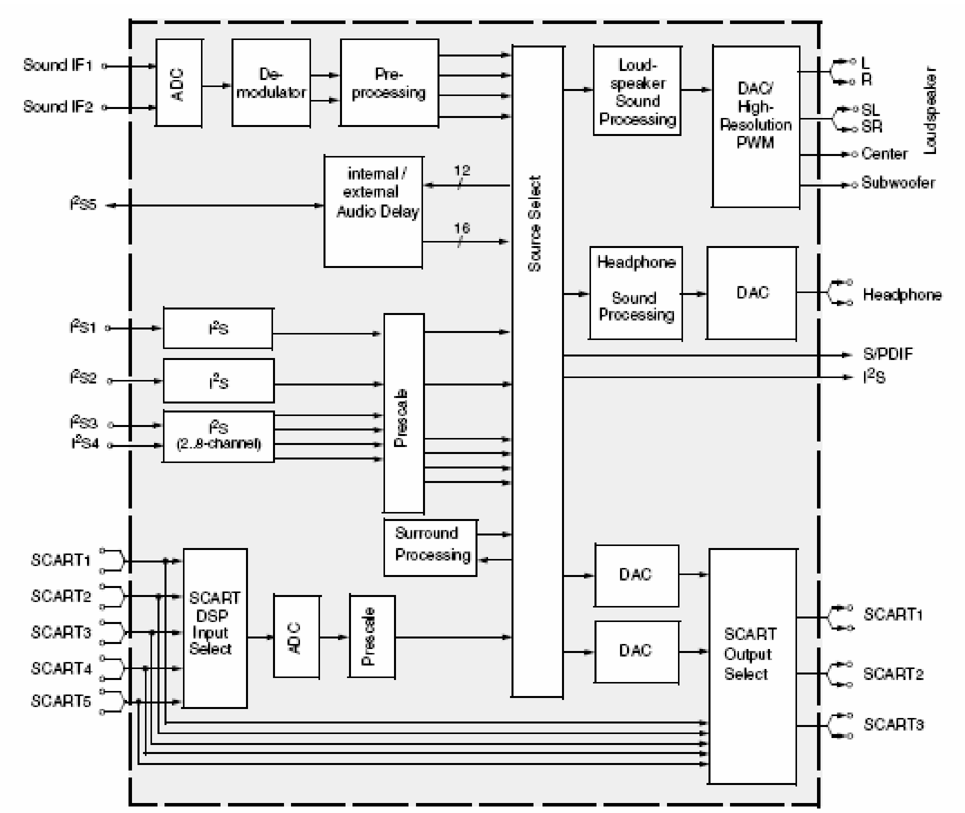


Figure 4.5 Internal blocks of audio processor (Micronas, 2006)

The output of the audio processor is baseband audio signal going to audio interfaces such speaker, headphone, scart out, subwoofer and etc.

4.1.6 Video Processor

The video processor used in the project is a very powerful IC that includes many video processing blocks inside and called SVP LX66. The roles of the video processor in the design are:

- To extract color, brightness, and synchronization information from CVBS; YPbPr, YC, RGB and digital video signals for panel TCON
- To extract and decode teletext information CVBS signal
- To carry out deinterlacing for FPD panel. Since FPDs use progressive scanning
- To do scaling to show different resolution video on a fixed resolution display
- To apply video enhancement algorithms to the video signal such as color, sharpness, contrast enhancement, motion compensation and etc.

The internal block diagram of SVP LX66 is shown in Figure 4.6.

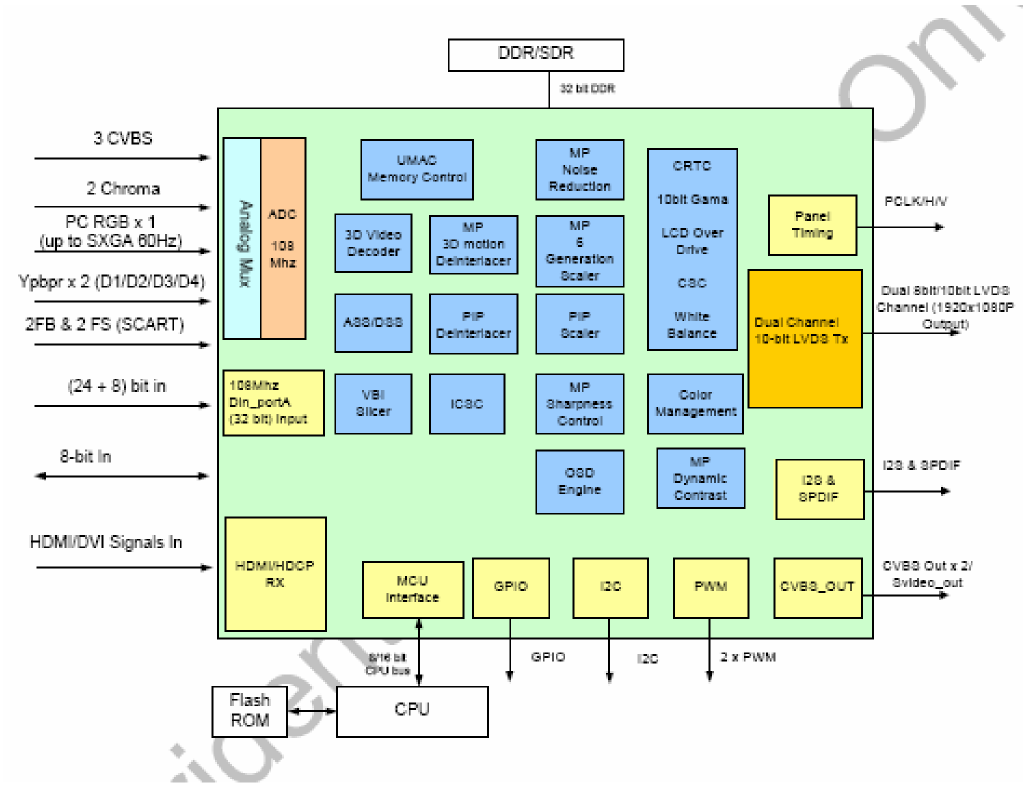


Figure 4.6 Internal block diagram of video processor (Trident, 2006)

The output of the video processor is LVDS signal to the panel TCON board, I2S output to the audio processor for HDMI. The LVDS signal carries digital color and synchronization information.

4.1.7 DDR SDRAM

Bandwidth is very important for video processing. Then, a DDR SDRAM (Double Data Rate SDRAM) is used for the video processor. EM6A9320 is a 4Mx32 RAM and used in the project. It has both CLK and CLK# which are complementary. Processing occurs at both of the rising edges of the CLK and CLK# in DDR RAM. Thus, the processing speed is twice of a normal SDRAM.

4.1.8 HDMI Switch

There are two HDMI (High Definition Multimedia Interface) inputs on the board whereas there is only one digital input for HDMI on video processor. Then an HDMI switch -AD8190- is used for 2:1 switching of HDMI inputs. The switch also has the equalization and preemphasizing the TMDS (Transmit Minimum Differential Signal- the format HDMI uses) properties. These properties compensate the effect of long transmission cable.

4.1.9 Video and Audio Switch

Because there are many audio and video interfaces to the board despite the limited numbers of audio and video inputs of audio and video processor ICs, audio and video switch ICs are used for selection of wanted channels for main and PIP/PAP picture. TEA6420 is the audio switch IC and TEA6415 is the video switch IC used in the project. These ICs are used for analogue audio and video signals. The selection is made via I2C commands coming from the microcontroller.

4.1.10 PIP Video Decoder

An additional feature of the design is displaying PIP (Picture in Picture) and PAP (Picture and Picture). Using this feature for two RF channels is possible if two tuners are used for RF demodulation. Thus a second tuner and a second IF demodulator TDA 9885 are used. PIP and PAP feature can be used for many video inputs such as scart and RF, RF and PC and etc. the video processor used in the project is able to achieve this operation by itself. However, one channel of the PIP and PAP video must be digital input of the video processor. Then, the wanted channel for PIP/PAP is selected by the video switch and goes to the video decoder VPC 323XD. The general block diagram of the video decoder is shown in Figure 4.7.

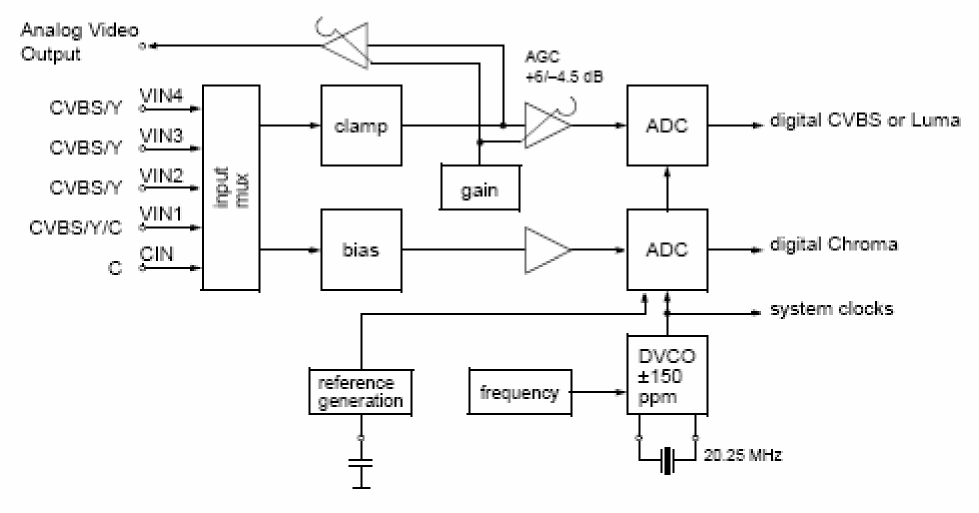


Figure 4.7 Internal blocks of video decoder (Micronas, 2001)

The output of the video decoder is 8 bits digital video going to the digital inputs of the video processor.

4.1.11 Microcontroller

Controller IC is the basic unit for all kind of embedded systems. The performance requirements of the controller depend on the FPD driver board requirement such as processing speed, number of IO pins, size of the memory and etc. the controller used in the project in the project is M16C which uses 16bit processing. It is the master IC in I2C communication. All user applications and system operation is controlled by the microcontroller. Also there are two additional memories are used for the controller. The first one is an EEPROM -24LC32- for keeping the user adjustments such as volume level, channel list and etc. The second one is a 16Mbit flash memory –MT28F800B3- to keep the source code run by the controller.

4.2 The Layout of the Board

Through the rough block diagram in Figure 4.1 and the IC specifications explained in preceding parts, the detailed block diagram of the driver board is drawn as shown in Figure 4.8.

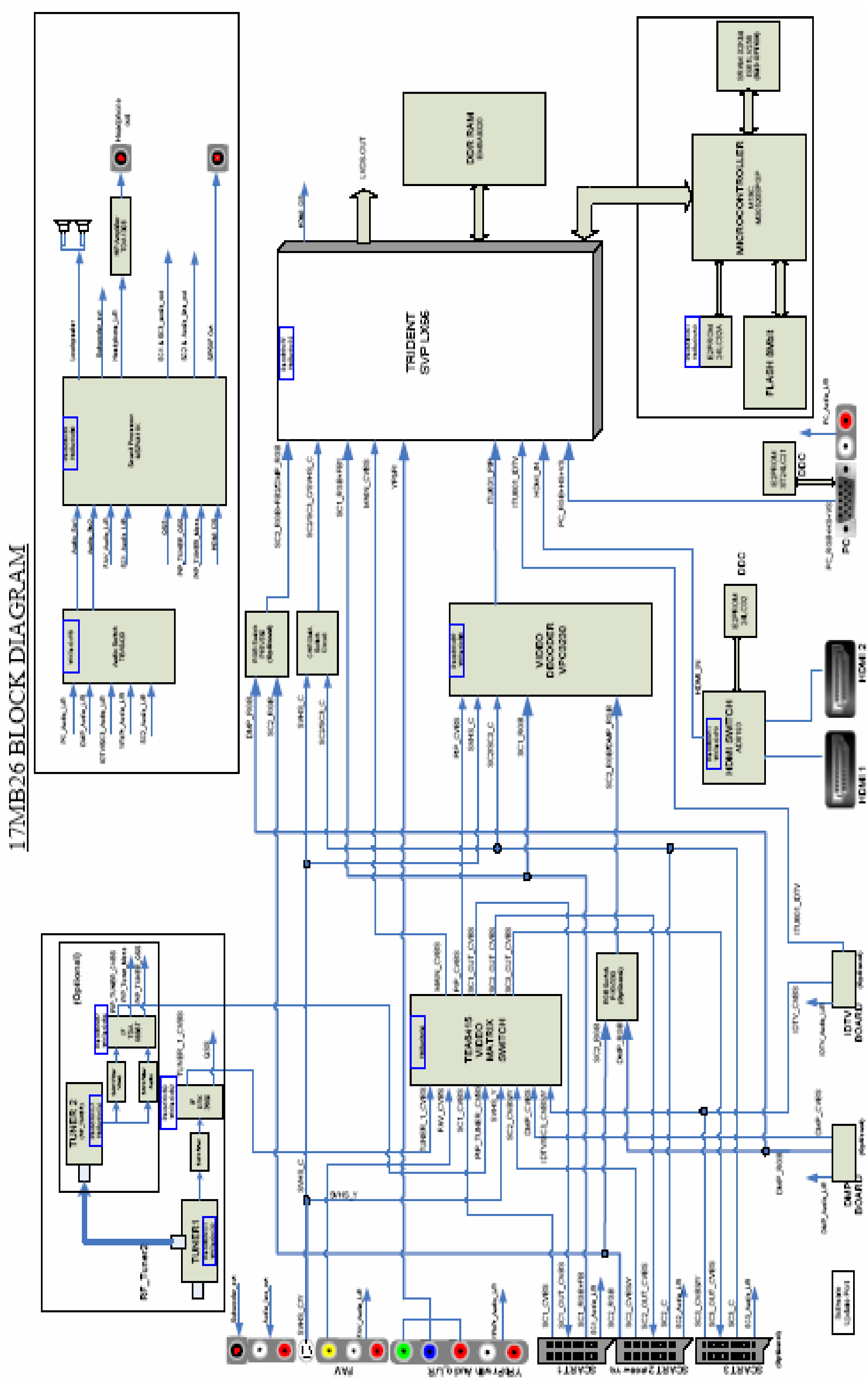


Figure 4.8 Detailed block diagram of the driver board

Once the detailed block diagram of the board is obtained, the schematic drawing starts. All connections of the ICs are made through the block diagram and IC datasheets. The recommendations from IC suppliers are always an important guide for the usage of the ICs. When the schematic drawing finishes, the layout drawing starts.

Layout arrangement of the components is a very important criterion for the performance of the board. Since too many components which has very low signal levels with high speeds are used. Then they have tendency to be affected from the electromagnetic interference produced by the board itself or other outside factors. The points that are considered during the layout arrangement are summarized below:

- Put the related ICs as close as possible to each other. For example video processor and DDR RAM must be close to each other to avoid electromagnetic radiation due to high speed (250MHz) digital communication between ICs. Also the IF block ICs must be place closely to avoid electromagnetic interference to IF signal on the path.
- Increase the number of layers of the PCB. This improves the EMC performance of the board for both emission and immunity. Four layer PCB is used in the design.
- Make the power and ground lines wider to avoid fluctuations on the IC supplies. This also avoids burning of the lines in case of short circuits on the board.
- Place switching ICs such as regulators away from other ICs to avoid interference at switching frequency.
- Protect sensitive lines by placing them between ground lines. This prevents crosstalk problems.
- Put return paths for different voltage levels to decrease electromagnetic radiation.

The layout drawn through this information is shown in Figure 4.9.

Figure 4.9 The layout of the FPD driver board

The designed FPD driver board with components is shown in Figure 4.10.

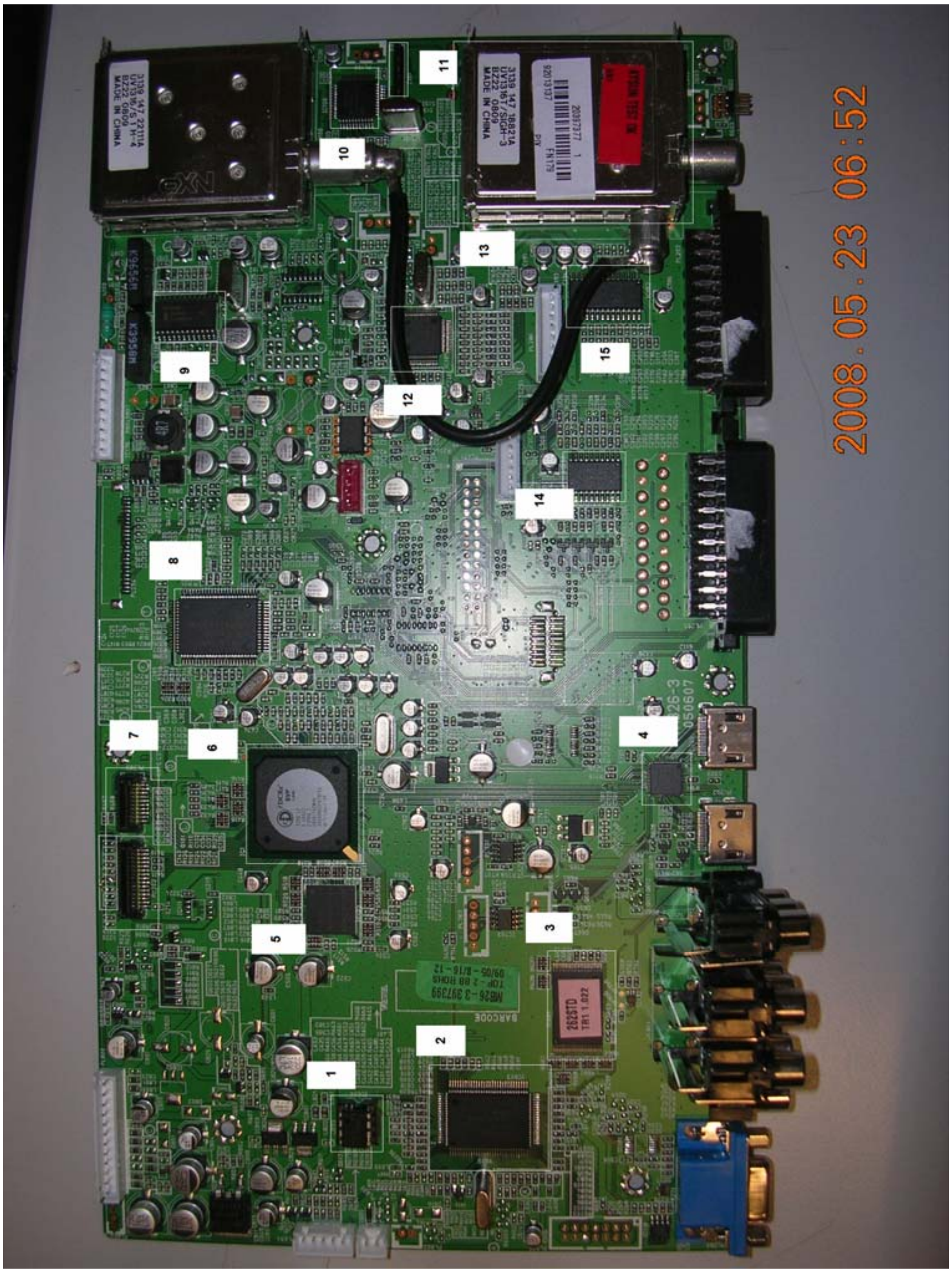


Figure 4.10 Designed FPD driver board

The ICs which are explained in Chapter 4.1 are shown with numbers on the layout. The ICs with numbers are given in Table 4.1.

Table 4.1. ICs shown in Figure 4.10

IC Number	IC Name
1	EEPROM
2	Controller
3	Flash
4	HDMI Switch
5	DDR RAM
6	Video Processor
7	LVDS Connector
8	Video Decoder
9	PIP IF Demodulator
10	Main IF Demodulator
11	SAW Filter
12	Audio Processor
13	Tuner
14	Video Switch
15	Audio Switch

The final layout of 17mb26 FPD driver board is shown in Figure 4.10. the changes made on the layout due to EMC problems will be explained and shown in the next chapter.

CHAPTER FIVE

ELECTROMAGNETIC IMMUNITY TESTS ON THE BOARD

The general working principles of the TFT TVs are explained in Chapter Two. EMC concept, immunity test definitions and procedures are explained in Chapter Three. Through this information, the electromagnetic immunity improvements of the TFT driving board designed in Chapter Four will be explained in this chapter.

As explained in Chapter Four, the RF to LVDS path of the video signal can be shown as in Figure 5.1.

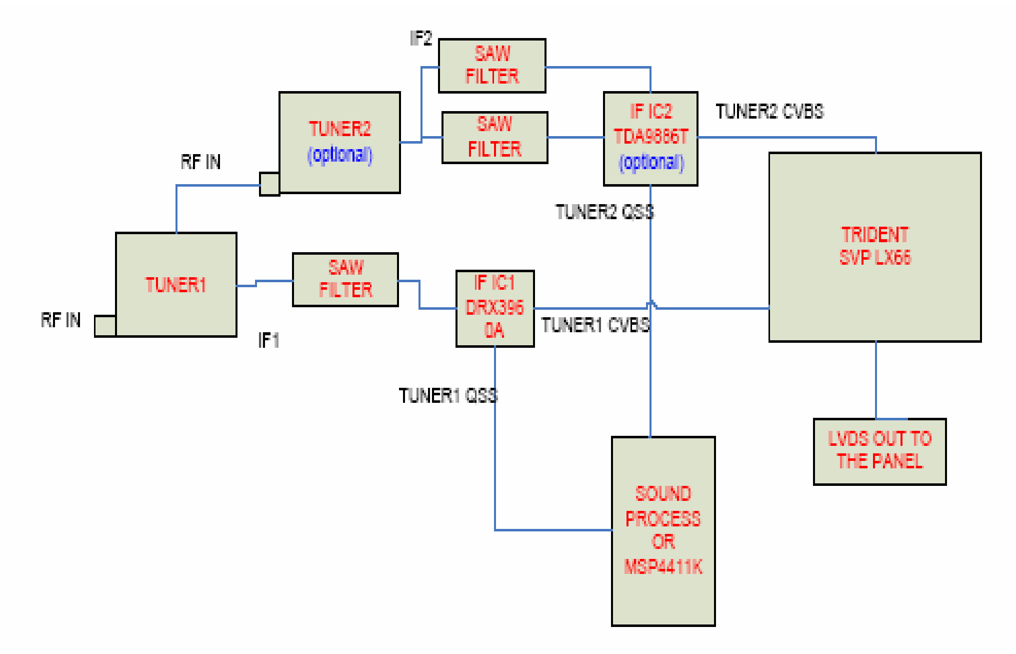


Figure 5.1 RF to LVDS path

The most important part of this path for S2C (immunity to RF voltages at antenna terminal) test is the path from RF to CVBS part.

The IF demodulator is very important for the S2C test. Since the role of the IF demodulator is to extract video and audio information from the IF signal. Any fluctuation on the electrical supply of the IC causes distortion on both audio and video which cannot be recovered at the rest of the system.

However, the IC must be placed near the tuner to keep the IF path as short as possible to avoid noise interference on IF signal. This structure is contradictory to the nature of the S2C test. Since, noise is injected to the system through antenna ground.

5.1 S2C Tests with the First Layout

The procedure to test the immunity of a TV receiver to voltages at antenna terminal explained in Chapter 3.4 is applied the designed FPD board 17mb26 explained in Chapter 4. No problem is recorded for audio performance. However the board failed at picture performance tests. The test graphic is shown in Figure 5.2. The horizontal axis shows the carrier frequency of the unwanted signal which is 26MHz to 30Mhz. The vertical axis is the level of unwanted signal. The limit is 126 dB(μV) and the test starts with 9 dB(μV) above the limit.

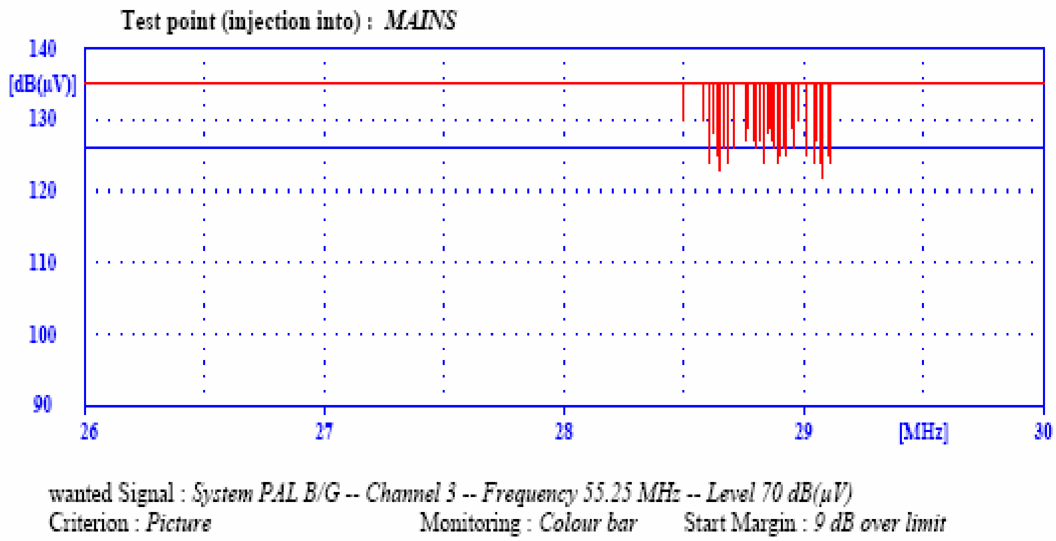


Figure 5.2 S2C test graphic with the first layout

During the test, carrier frequency of the unwanted signal is changed from 26MHz to 30Mhz while observing the picture on TV. If any degradation is observed, the level of the noise is decreased. If the degradation disappears above the limit, the margin for that frequency is recorded and the test continues with the next frequency. If any change is made on the EUT, the test is started again. Since the changes on the EUT may shift the frequency which the degradation is observed. The degradation of the picture is shown in Figure 5.3.

Figure 5.3 The degradation of the picture during S2c test

The interference can easily be observed in the shape of horizontal bars. These bars are caused due to interfering modulated sine wave. The degree of the interference in the picture changes according to modulating frequency of the noise. The test report is given in Figure 5.3.

Frequency [MHz]	Level [dB(µV)]	Limit [dB(µV)]	Margin [dB]
28,5	130,0	126,0	4,0
28,58	130,0	126,0	4,0
28,61	124,0	126,0	-2,0
28,62	128,0	126,0	2,0
28,64	125,0	126,0	-1,0
28,65	123,0	126,0	-3,0
28,67	126,0	126,0	0,0
28,68	124,0	126,0	-2,0
28,71	126,0	126,0	0,0
28,76	127,0	126,0	1,0
28,77	129,0	126,0	3,0
28,79	127,0	126,0	1,0
28,8	126,0	126,0	0,0
28,82	127,0	126,0	1,0
28,83	124,0	126,0	-2,0
28,85	128,0	126,0	2,0
28,86	129,0	126,0	3,0
28,87	127,0	126,0	1,0
28,88	126,0	126,0	0,0
28,89	124,0	126,0	-2,0
28,9	125,0	126,0	-1,0
28,92	126,0	126,0	0,0
28,93	125,0	126,0	-1,0
28,95	129,0	126,0	3,0
28,96	126,0	126,0	0,0
28,98	130,0	126,0	4,0
29,01	125,0	126,0	-1,0
29,04	124,0	126,0	-2,0
29,05	127,0	126,0	1,0
29,07	124,0	126,0	-2,0
29,08	122,0	126,0	-4,0
29,1	125,0	126,0	-1,0
29,11	124,0	126,0	-2,0

Figure 5.3 S2C test report with the first layout

The test report and the graphic shows that the results are below the limit and the TV does not satisfy EMC immunity criteria. To improve the immunity of the board, the layout is inspected and below points are recognized as the reason for the failure:

- SAW filter is very close to the tuner
- There is no separation between the tuner, SAW filter and IF demodulator ground.

The layout arrangement of tuner the tuner area is shown in Figure 5.4 in detail to examine above points.

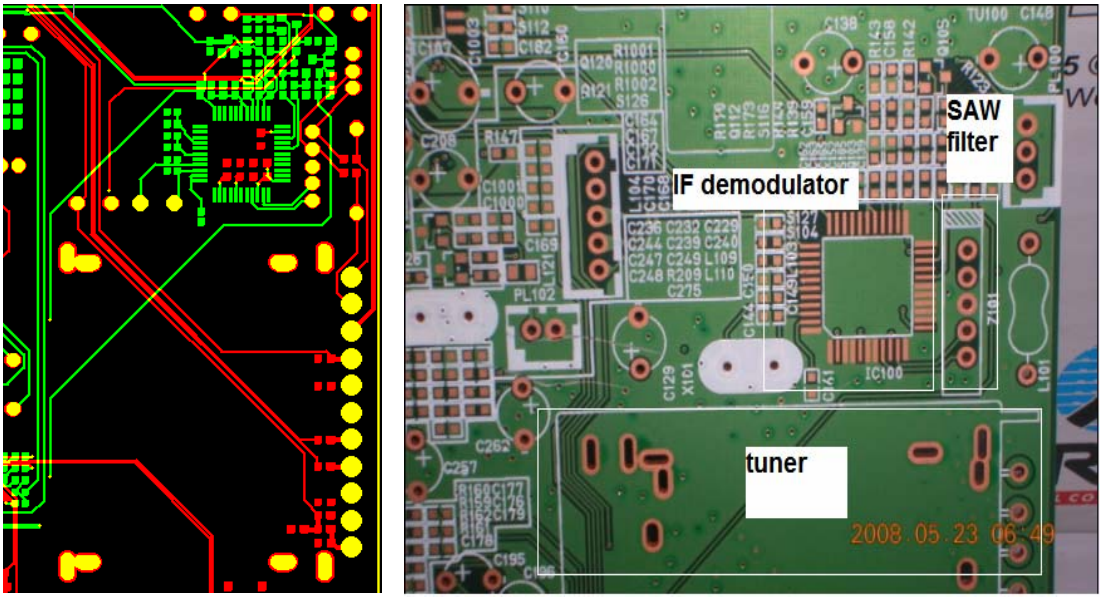


Figure 5.4 The tuner layout structure in the first layout

5.2 Trials to Increase the Board Immunity

To make the system more immune to the injected noise the methods explained below are applied:

- SAW filter is desoldered from the PCB. The connection is made with wires and the effect of the distance between the tuner and the filter is observed. The more away the SAW filter from the tuner, the better was the results. Changing the direction of the filter has improved the results. Since the output of the SAW filter gets away from the tuner and noise interference from the tuner is reduced.
- The ground surface was unbroken through the tuner, the SAW filter and the IF demodulator. This allows the injected noise from antenna ground to reach the IF block and reduces TV the performance during the test. To see the effect of ground separation, the ground plane connecting the tuner and IF IC is separated by cutting the surface. This modification made great improvement on the picture.

5.3. Examination of the Test and Video Signals

As explained in previous chapters, the applied wanted signal to the EUT is colorbar pattern. To see the effect of the unwanted signal on the video signal, the video signal is examined without unwanted signal. The CVBS signal for the wanted signal, which is the output of the IF demodulator, is shown in Figure 5.5 without unwanted signal.

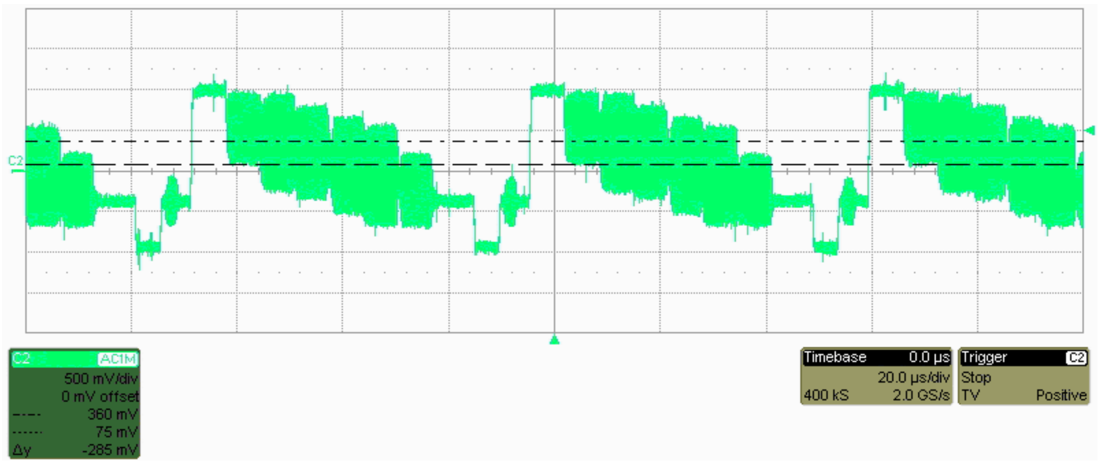


Figure 5.5 CVBS signal without unwanted signal

In the second step, the unwanted signal is examined from the can of the tuner and shown in Figure 5.6. As expected the unwanted signal is 1KHz sine with 80% AM modulation. The envelope of the unwanted signal 1KHz as in Figure 5.6 and the modulation frequency can be read in Figure 5.7 when the the signal is examined in a narrow time scale. The measurements are taken at 26MHz which is the read frequency in Figure 5.7.

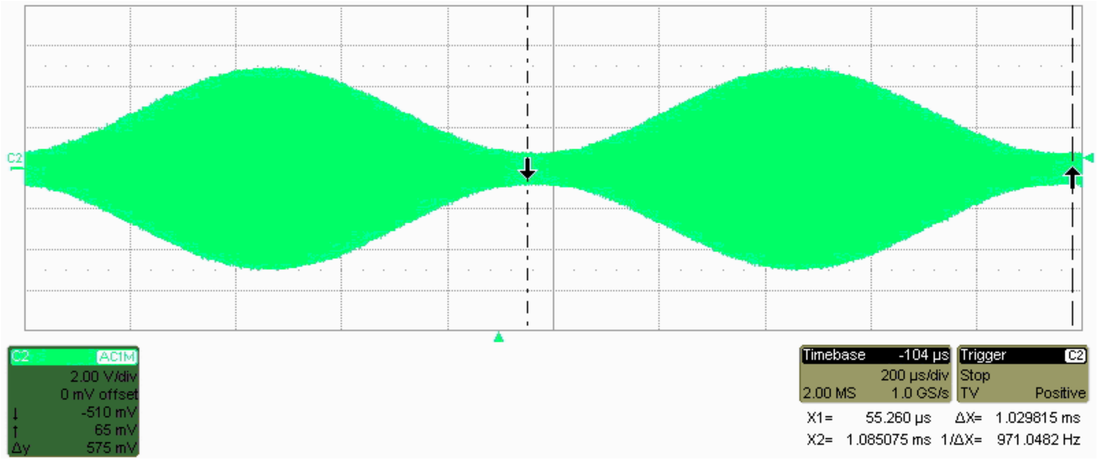


Figure 5.6 The unwanted signal

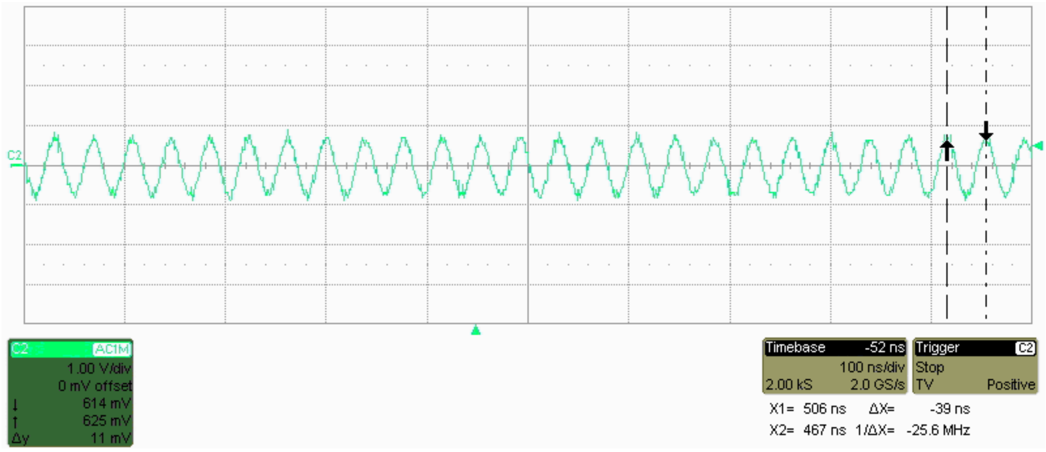


Figure 5.7 The unwanted signal with a narrow time scale

The video signal after the unwanted signal applied is shown in Figure 5.8.

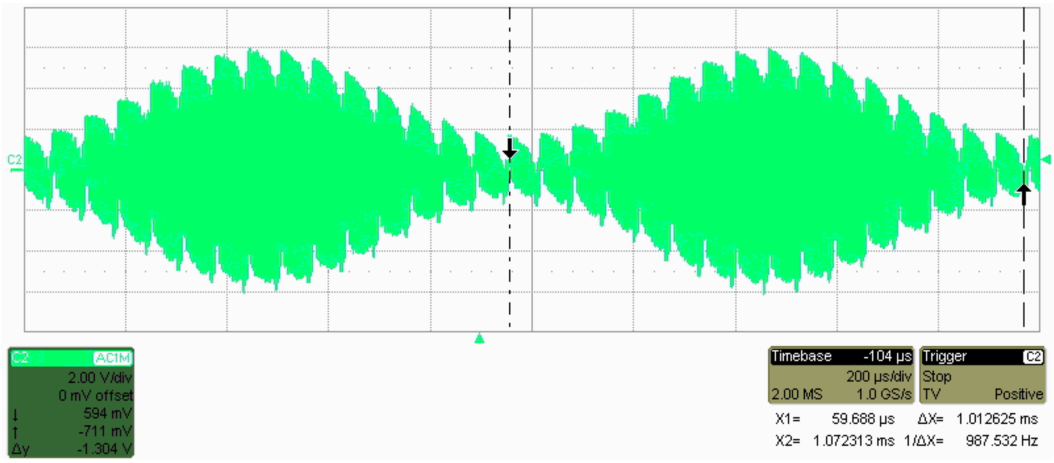


Figure 5.8 Video signal with unwanted signal applied

Figure 5.8 shows that the unwanted signal is added to the wanted video signal and the video signal is in the envelope of the 1KHz sine. Thus the white bars are seen on the picture.

5.4 S2C Test with the Second Layout

The layout change is made through the information in Chapter 5.2. The tuner part of the second layout is shown in Figure 5.9 and the board is shown in Figure 5.10.

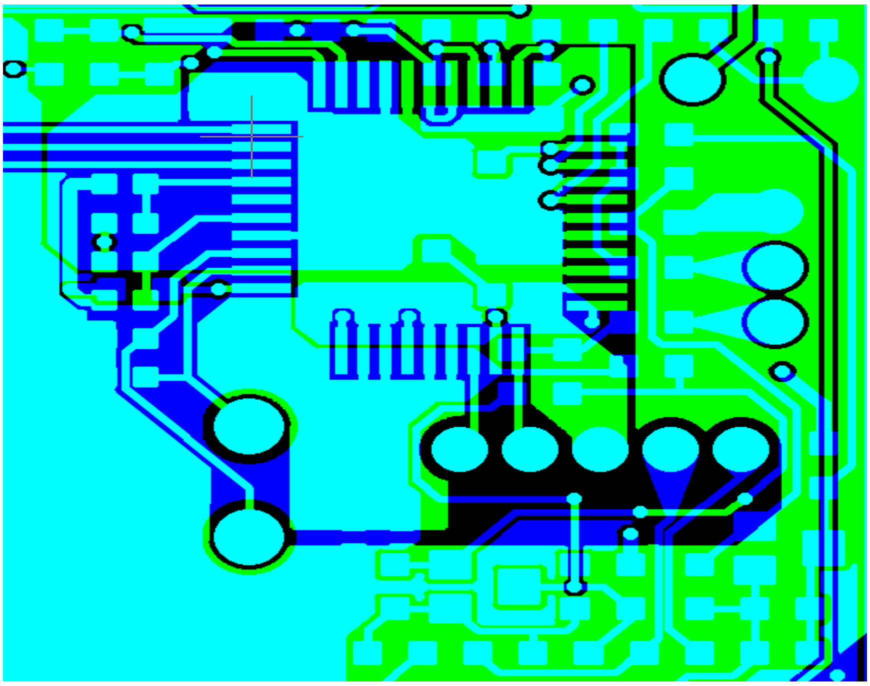


Figure 5.9 The tuner part of the second layout

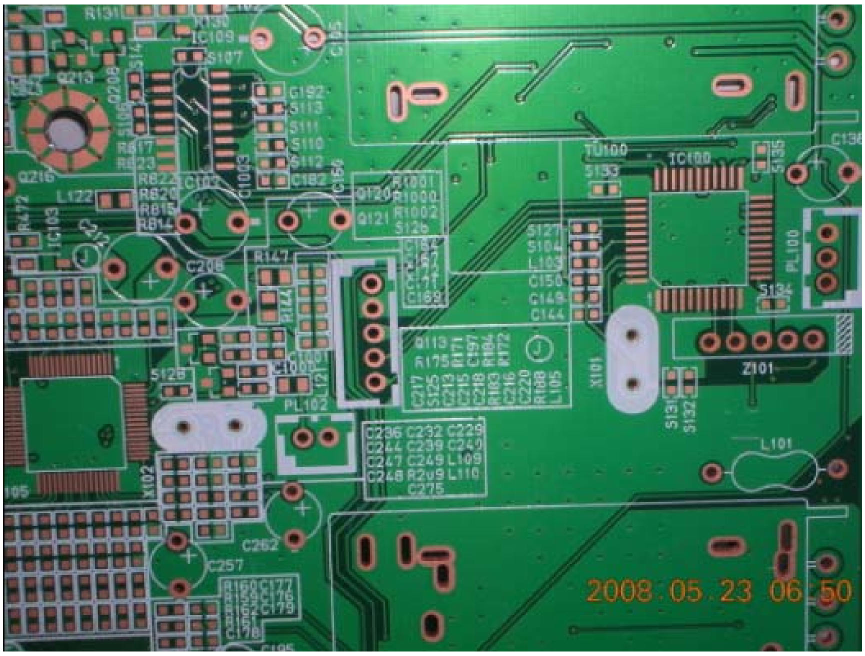


Figure 5.10 The tuner part of the board

The change may be observed by comparing the first and second layout as shown in Figure 5.11. The first layout is shown on the left and the second layout is shown on the left.

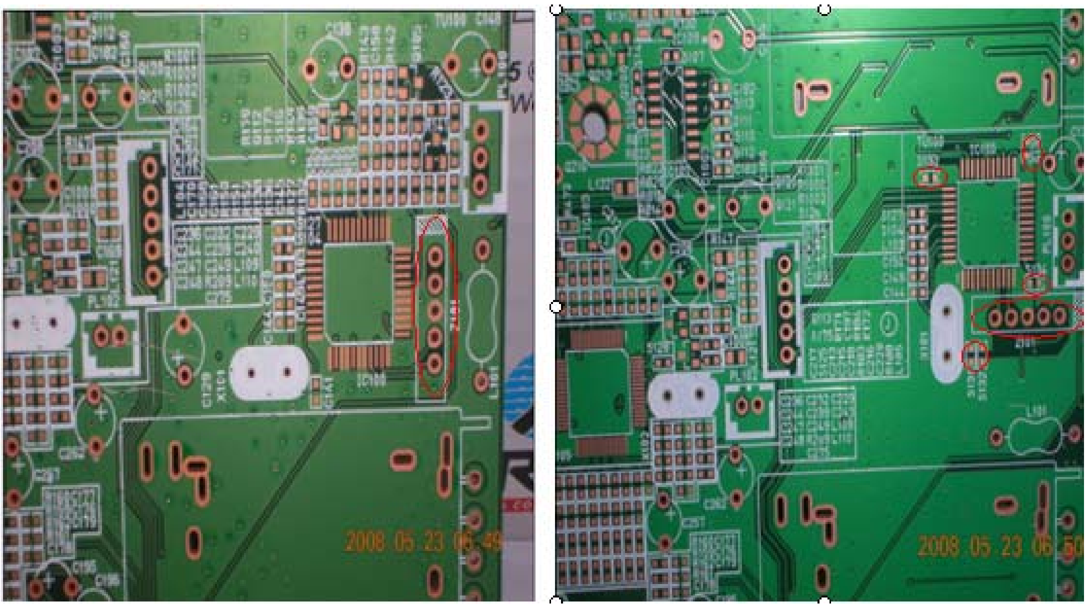


Figure 5.11 The first and the second layout comparison

In the second layout, the direction of the SAW filter is changed and it is placed away from the tuner. Also the input and output paths are made 180^o apart from each other to avoid the interference from input to output.

The most important change is separating the SAW filter and IF demodulator ground from tuner ground. This separation can be observed in Figure 5.9 and Figure 5.10. The SAW filter and IF demodulator ground are separated from the system ground through jumpers s131, s132, s133, s134, s135.

The test results with the second layout when all jumpers are connected are shown in Figure 5.12 and Figure 5.13.

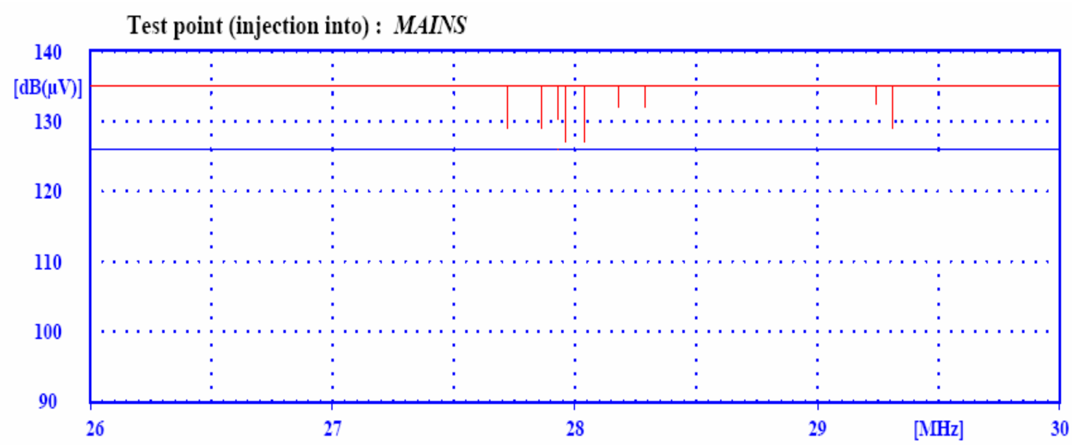


Figure 5.12 S2C test graphic for all jumpers connected in the second layout

Frequency [MHz]	Level [dB(µV)]	Limit [dB(µV)]	Margin [dB]
27,72	129,0	126,0	3,0
27,86	129,0	126,0	3,0
27,93	131,0	126,0	5,0
27,96	127,0	126,0	1,0
28,04	127,0	126,0	1,0
28,18	133,0	126,0	7,0
28,29	133,0	126,0	7,0
29,25	133,0	126,0	7,0
29,4	129,0	126,0	3,0

Figure 5.13 S2C test report for all jumpers connected in the second layout

The results are above the limit. However, 3dB test margin is required to allow the variation between the TVs and the test equipment. Although the test laboratories are accredited by legal commissions, there is some accepted deviation between the laboratories. The measurement results may change in different test suits. Thus, it is required to have some margin for the test.

To provide the required limit, s131 and s132 are removed from the board as shown in Figure 5.14 and the test is repeated. 3 dB margin is achieved as shown by the reports in Figure 5.15 and 5.16. The TV is approved by the EMC laboratory with these changes.

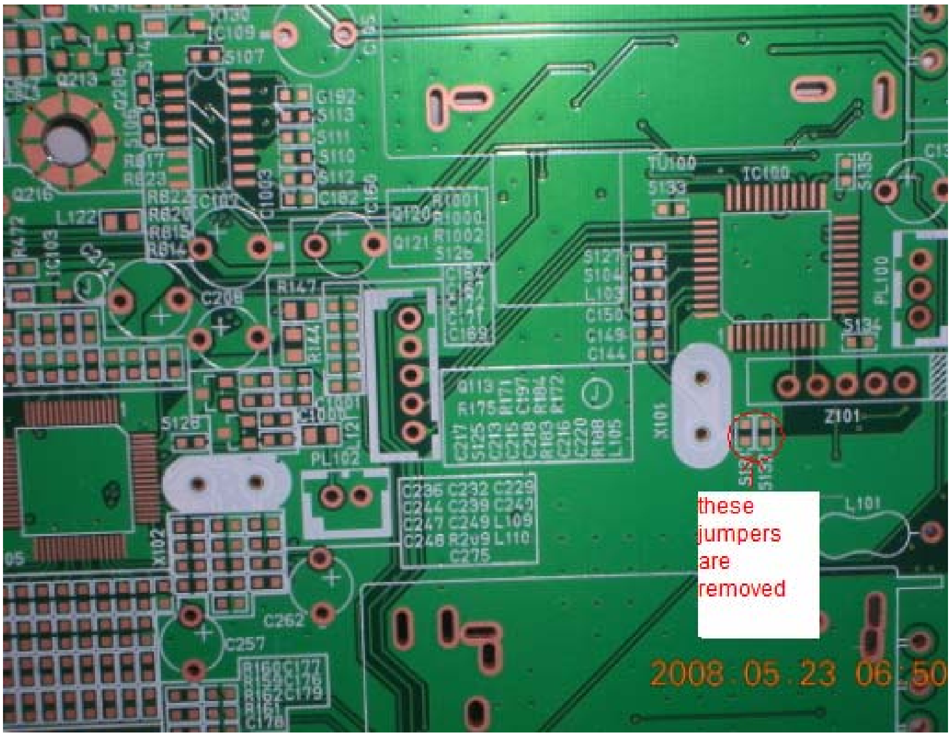


Figure 5.14 The jumpers removed to increase immunity

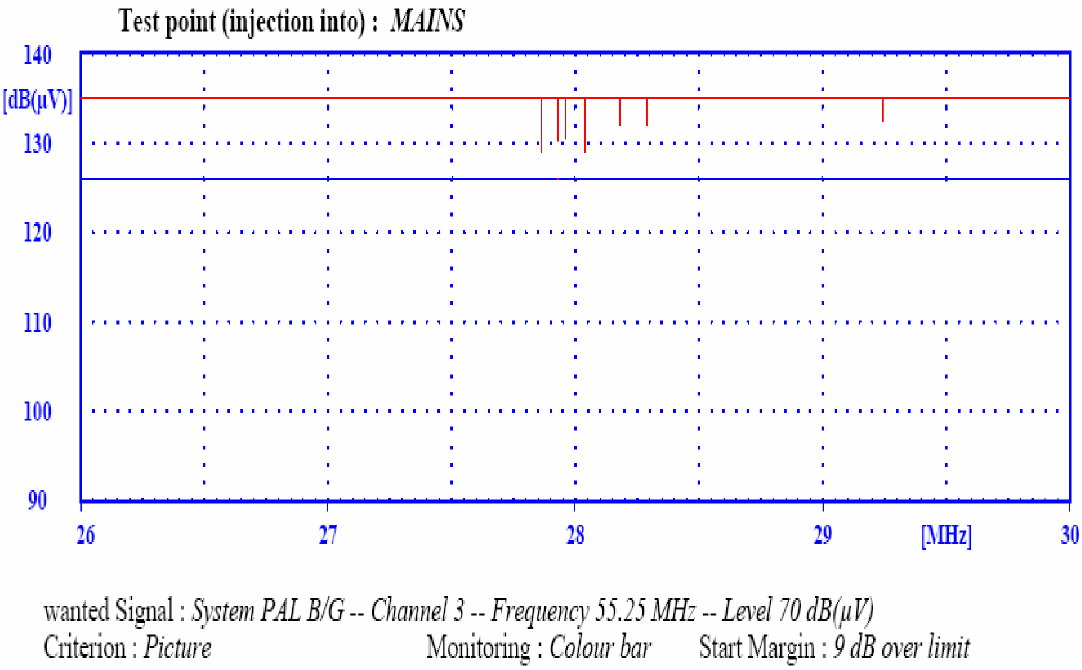


Figure 5.15 S2C test graphic with the second layout, two jumpers removed

Frequency [MHz]	Level [dB(µV)]	Limit [dB(µV)]	Margin [dB]
27,86	129,0	126,0	3,0
27,93	131,0	126,0	5,0
27,96	131,0	126,0	5,0
28,04	129,0	126,0	3,0
28,18	133,0	126,0	7,0
28,29	133,0	126,0	7,0
29,25	133,0	126,0	7,0

Figure 5.16 S2C test report with the second layout, two jumpers removed

CHAPTER SIX

CONCLUSION

Flat panel display technology is taking place in television market with growing share. Flat panel displays use liquid crystals as the main material for the control of light passage and thin film transistor (TFT) technology as the control circuitry of the liquid crystal. The addressing of the transistors and the amount of current that drives them are controlled by timer controller (TCON) board of the panel. The necessary video information and control signals for synchronization to display pictures on the panel are supported by FPD driver board.

FPD driver board achieves video and audio reception from broadcast or other analogue and digital video/audio interfaces such as scart, HDMI etc. Then, selected video and audio channel is processors to improve video and audio quality. The output of the audio processor is converted to hearable audio by the speaker, headphone and other converters. The output of the video processor is in LVDS (Low Voltage Differential Signal) format and contains digital video information and synchronization signals. These data are used by TCON for displaying pictures.

Electromagnetic compatibility (EMC) is an important issue for proper operation of electronic and electrical devices. Every electronic device can be a source or a victim for electromagnetic phenomena. To provide an environment that is safe in electromagnetic point, the emission and immunity levels are regulated by the standards published by international organizations. Every electronic and electrical device has to comply with these standards to have CE marking to enter Europan Market.

The immunity of a television to induced RF voltages at antenna terminal is very important for the picture and audio performance. The limits of interference to antenna terminal are determined by the standard CISPR20 by IEC. This test simulates the current induced on the antenna cable, interfering the system through antenna ground. The effect of this interference is reduced signal to noise ratio for audio and distortion for the picture.

The immunity problem of the designed FPD driver board is overcome by the changes in layout arrangement. Separating the susceptible ICs, which are IF demodulator and SAW filter, from antenna ground increases the immunity performance of the board. Changing the direction of the SAW filter and putting it away from the tuner decreases the electromagnetic interference to SAW filter and IF signal which is another factor increasing the immunity of the board. The performance of the board with this layout design is approved by EMC tests and reported. Thus, this layout structure is accepted as a reference for future designs to minimize the cost and time consumption for EMC immunity to RF voltages at antenna terminal (S2C) tests.

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APPENDICES

Appendix A. Coupling Units

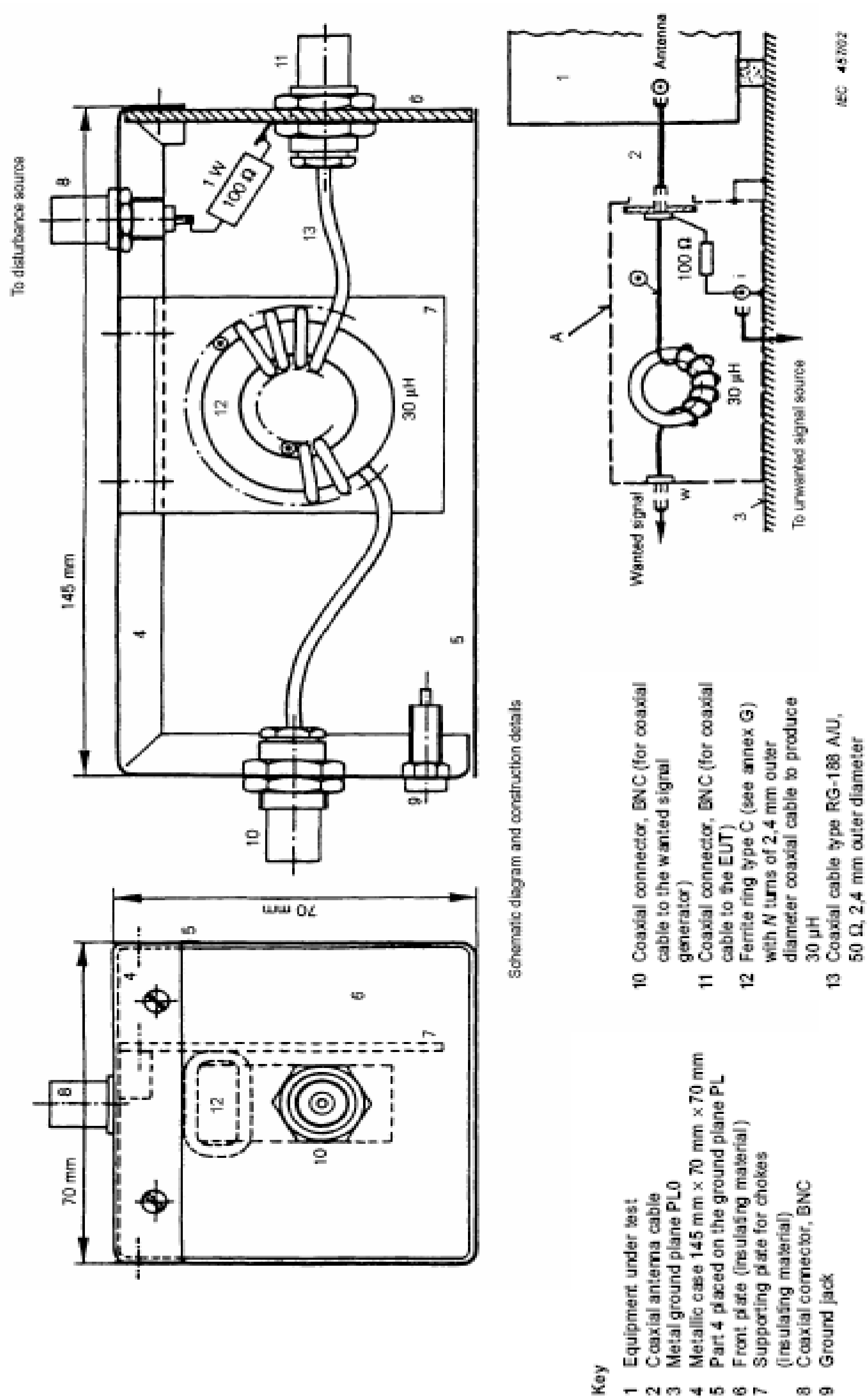


Figure A.1 Coupling unit type AC (for coaxial antenna input)

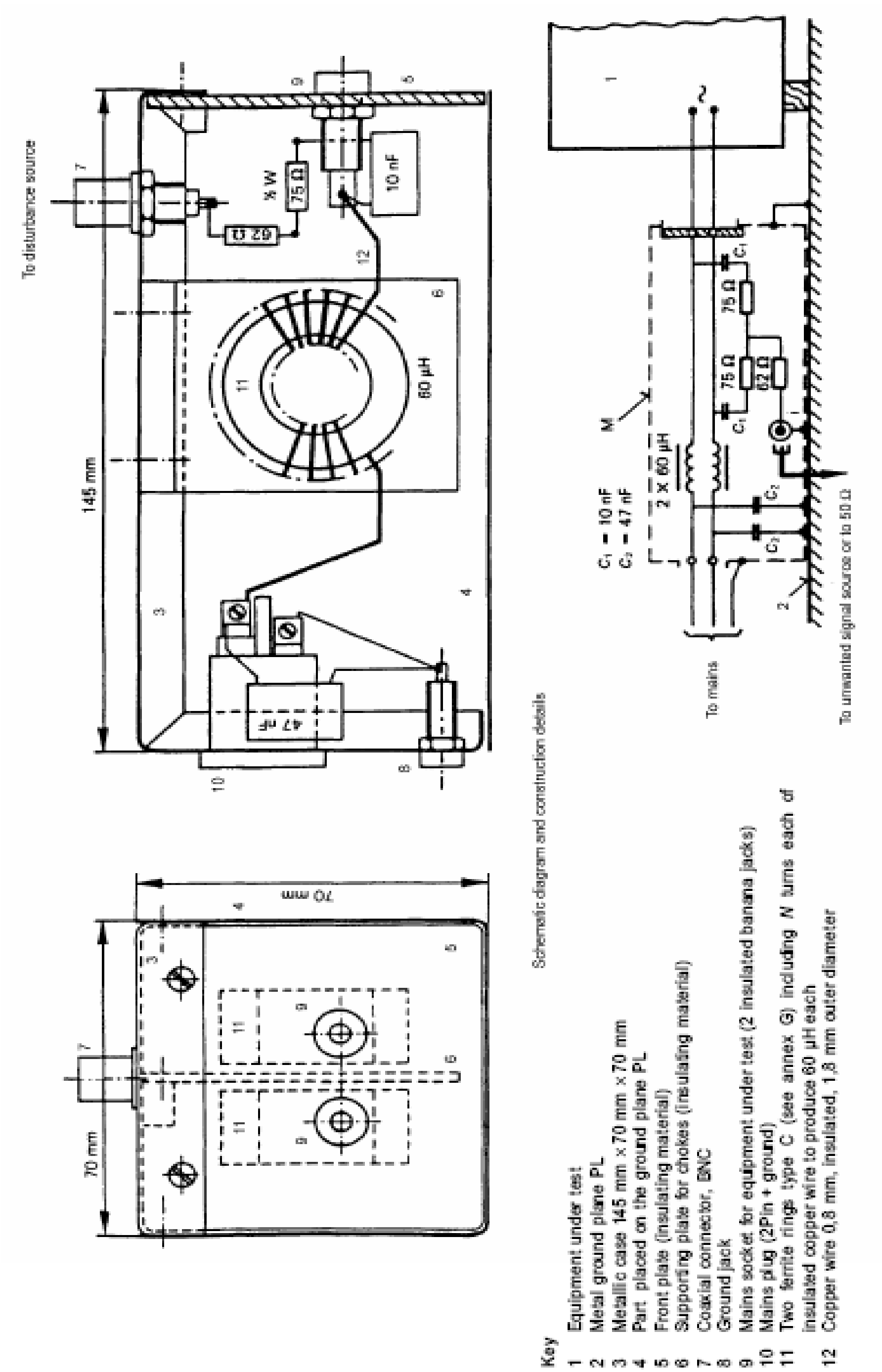
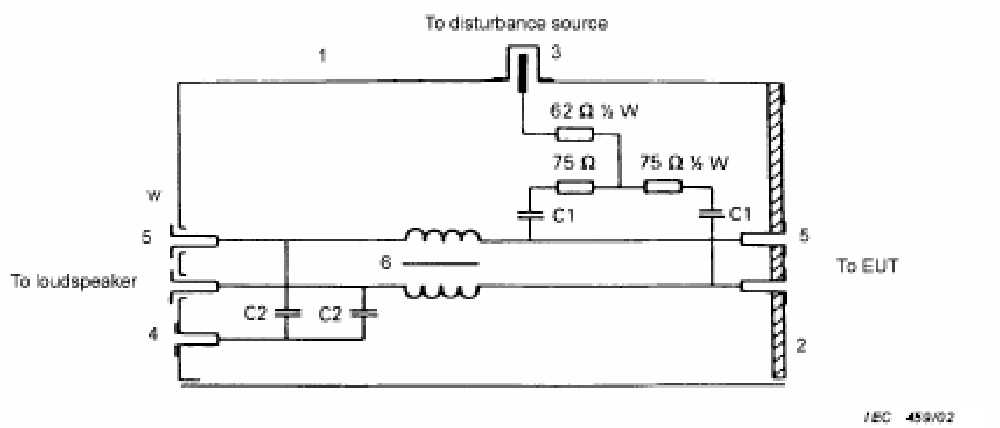


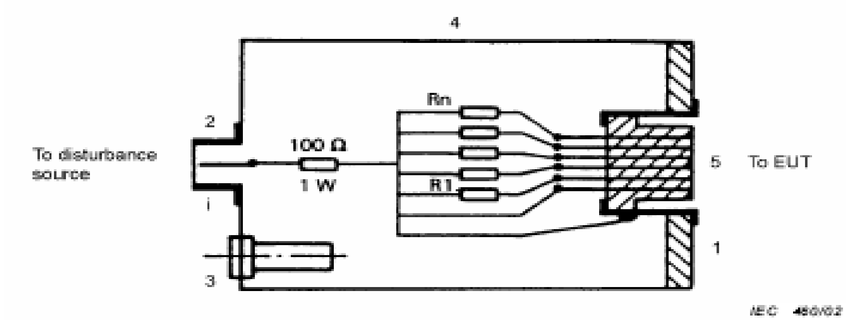
Figure A.2 Coupling unit type MC (for mains lead)



Key

1 Metallic case 145 mm × 70 mm ×70 mm
2 Front plate (insulating material)
3 Coaxial connector, BNC
4 Ground jack
5 Insulated banana jacks
6 Inductance 30 µH asymmetrical
Core: 1 ferrite ring, type C (see Annex G).
Winding: *N* turns with a twisted pair (2 leads, copper wire 0,6 mm diameter, insulated, 1,2 mm outer diameter to produce 30 µH).
Mounting of the inductance similar to Figure C.1.
Capacitors: C1 = 10 nF; C2 = 47 nF.

Figure A.3 Coupling unit type LC (for loudspeaker leads)



Key

1 Front plate (insulating material)
2 Coaxial connector, BNC
3 Ground jack
4 Metallic case 100 mm × 55 mm × 55 mm
5 Multiple pins connector or DIN-socket

R1 to Rn matched load resistance

Example: Coupling units Sr for audio equipment:

Phono magn.: 2 × 2,2 kΩ
Phono crystal: 2 × 470 kΩ
Microphone: 2 × 600 Ω
Tuner: 2 × 47 kΩ
Tape in/out: 4 × 47 kΩ
Audio in/out: 4 × 47 kΩ

Figure A.4 Coupling unit type Sr with load resistances