

DIGITAL SIGNAGE EQUIPMENT FOR GAS STATION PUMPS APPLICATION

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In this paper is described the design, prototyping and operating of a digital signage equipment fated to be used on gas station pumps. Because of the high risk degree of the place where is mounted the equipment (the surrounding atmosphere contains gas vapors), special safety measures were took in the design.

Keywords: gas station digital signage equipment, XGA transmission over long, distance, high brightness LCD, phantom power, LED backlight inverter, RF touchscreen, cooling system

1. Introduction

In the last years there has been an increasing demand for digital signage equipments in gas station pumps outdoor applications. Big players on the market like Intel, Hyundai, Gilbarco Veeder-Root or Delphi Display Systems are producing digital signage equipments to stream video from a central content server via wireless or wired connectivity. These equipments (e.g. Hyundai T2010, H2010) are directly connected to AC main voltage. Oil companies are offering content and advertising on color screens integrated directly into fuel dispensers[1]. Their request from electronics industry is to provide a cheap, low-power and reliable equipment, as described in this article. A special care should be done when designing such equipments: a complete isolation from external environment, waterproofing, cables isolation, working temperatures below 60°C. Each unit mounted on the fuel dispenser is called “Receiver module”. It includes two liquid crystal display modules (LCD) with peripherals, one extended graphics array (XGA) distributor and a twisted pair (TP) to XGA converter (TP/XGA). The source signal comes from desktop computer, DVD player, laptop, etc., located in a building far enough from the dangerous site. Signal is then applied through a XGA 1:3 distributor to some XGA/TP converters. These converters are used to send the information through twisted pair cables to 3 receiver units mounted on

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fuel dispensers. In receiver module, the signal is converted back into analog XGA through TP/XGA converter. To assure a satisfactory signal/noise (S/N) ratio, the distance between these converters should not exceed 200 feet (60 meters). Video signal is splitted in two paths with a XGA 1:2 distributor, and it is finally displayed on two LED backlight LCD modules. All parts in receiver module are mounted in a parallelepiped aluminum box, completely sealed from external environment. Aluminum cover permits good heat exchange with outside environment and an easy mechanical manufacture. Anti vandal security windows are mounted at box extremities, in order to access LCD information and to protect against thieves. To permit a clear image in the situations when the box is mounted in sunny environment, a high brightness type LCD module was chosen.

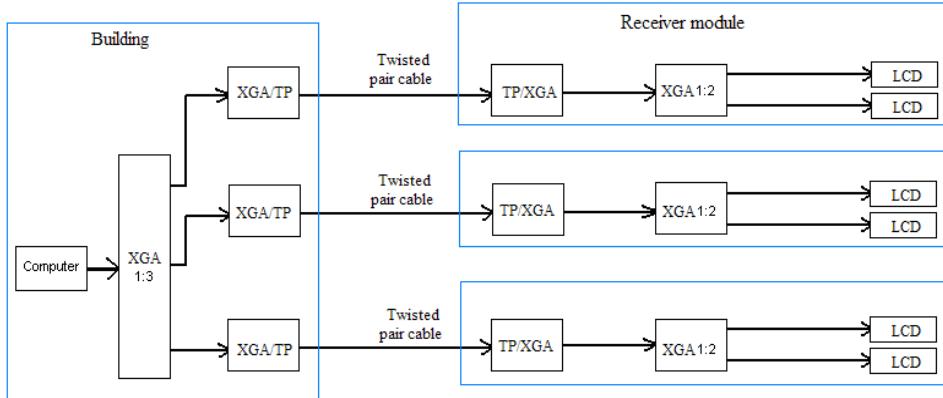


Fig. 1. Signal path in digital signage application

2. XGA 1:3 distributor

This unit is used to distribute XGA signal to the XGA/TP converters. To assure enough resolution bandwidth, 1GHz high band-pass ultrahigh speed current feedback amplifiers are inserted on red, green and blue paths. The signal is applied to the input input through a VGA cable which connects the computer with the distributor.

As shown in fig. 2, input impedance is set by R1 resistors at 75Ω (standard value). D1-D3 diodes protect the inputs against electrostatic discharge (ESD). Diodes will drive only when input voltages are lower than -0.6V or greater than 5.6V. Integrated circuit on video path is configured as non-inverting operational amplifier with a fixed gain given by the following equation[2]:

$$A_V = 1 + \frac{R_2}{R_6}, |A_V| = 2 \quad (1)$$

Output signal is divided by two using R7 resistor (75Ω) and internal resistor mounted inside XGA/TP converter (75Ω). Considering the global voltage gain (between computer and XGA/TP converter), we have a unity value. This

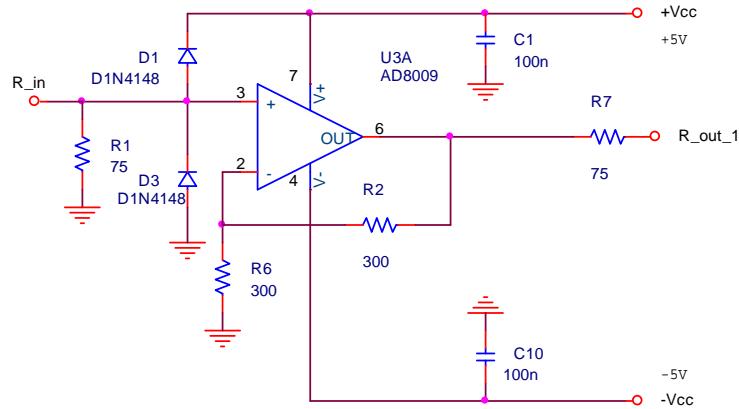


Fig. 2 Signal amplifier example for red channel (extracted from schematic diagram)

scheme is referred to as “back termination” and is used when the driver is a low output impedance voltage source. Back termination requires that the voltage of the signal be double the value that the monitor sees. R, G, B channels separation is done by interconnecting an operational amplifier between common input and the output for each section. This eliminates channels interferences because of different grounding points or signal reflexions on transmission lines (at the end of each line is a complex impedance). Operational amplifiers are used at $\pm 5V$ supply voltages. Low inductance ceramic SMD (surface mount device) capacitors (C1, C10) are mounted on both ± 5 supply lines as close as possible V+ and V- terminals.

The integrated circuit (IC) U12 provides six precision Schmitt-triggers with non-inverting buffers. IC is used to transform horizontal and vertical synchronization pulses from computer video processing chip into sharply-defined, jitter-free sync signals. R11 and R12 resistors do both logical low level settlement when no signal is applied (0V) and impedance matching with the video processing chip synchronization outputs. D4 and D5 are input ESD protection diodes (Zener type). First 3 buffers of U12 have the inputs connected together (1A, 2A, 3A) and receive Hsync signal from computer card. Buffers outputs (1Y, 2Y, 3Y) are connected through 75Ω resistors to perform impedance matching. Last 3 buffers have the inputs (4A, 5A, 6A) tied together to Vsync computer signal. Their outputs deliver also Vsync through 75Ω impedance matching resistors.

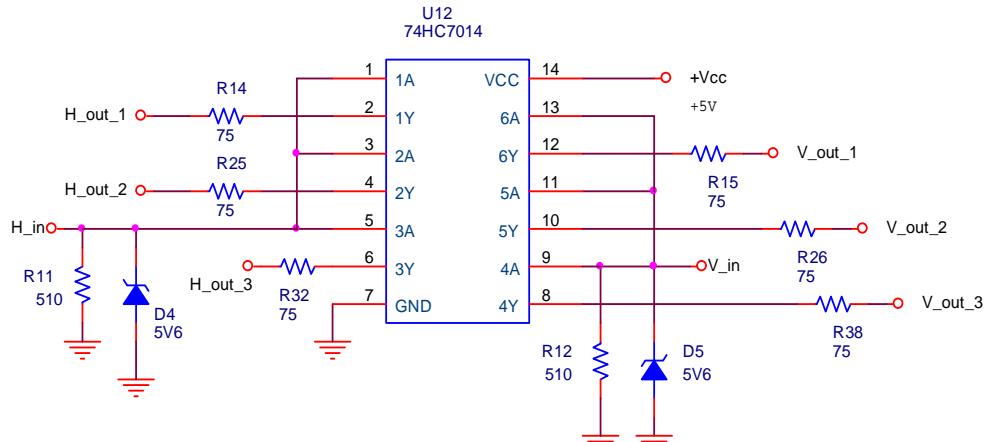


Fig. 3 Sync buffer (extracted from schematics)

Voltage supply circuit is built around U1 and U2 IC's: U1 is a positive linear regulator which delivers power to entire circuit and U2 is a high-efficiency step-down and inverting DC/DC converter which provides -5V voltage to R, G, B amplifiers.

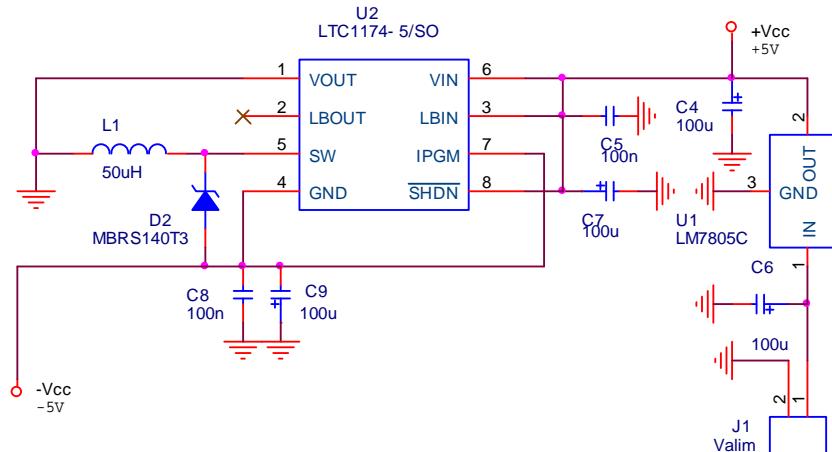


Fig. 4 Power supply circuit

A power supply adapter is connected to U1 IC through J1 connector. C6 capacitor (electrolytic type) filters input voltage ripple. U1 is mounted on a heatsink to permit semiconductor heat dissipation for case temperatures below 85°C. C4 should be tantalum type or low ESR (equivalent series resistance) for SMPS (switched-mode power supply) noise reduction and low ripple output voltage. Meanwhile U1 supplies operational amplifiers, DC/DC converter and U12 buffer. Current consumption value is given by the formulas:

$$I_{U1} = n \cdot I_{V+} + I_{U12} + I_{U2} \quad (2)$$

$$I_{U12} = n_B \cdot I_B \quad (3)$$

$$I_{U2} = \frac{n \cdot I_{V-}}{\eta} \quad (4)$$

where $n=9$ is the number of operational amplifiers, η is the DC/DC converter efficiency, $n_B=6$ the number of non-inverting buffers and I_B is the buffer supply current. We notice that in U2 situation the same output voltage modulus is delivered to the IC output ($|V_-| = |V_+|$), so output current will be equal with input current if converter has no losses. Considering:

$$|I_{V+}| = |I_{V-}| = 20mA \quad (5)$$

$$\eta = 0.8 \quad (6)$$

$$I_B = 7mA \quad (7)$$

we have a maximum power supply sink I_{U1} value below 500mA.

3. XGA/TP converter

XGA to twisted pair conversion is made by a high bandwidth triple differential twisted-pair driver with common-mode Sync encoding circuit[3]. This circuit provides three fully differential speed amplifiers, used in our application for driving high-resolution video signals onto TP cables. Internal amplifiers provide a fixed gain of +2 to compensate voltage losses on termination resistors. Horizontal and Vertical sync signals (Hsync and Vsync) are passed to an internal logic encoding block to encode the sync information as three discrete signals of different voltage levels, so analog video signals are sent through 3 pairs of cable. Through a phantom power technique the 4-th pair from TP cable supplies receiver module. Each operational amplifier output common voltage may be controlled by internal voltage reference V_{REF} . V_{REF} is delivered by logic encoding block, so U1 outputs deliver 3 video signals which includes R, G, B primary colors video components transmitted in full differential mode with Hsync and Vsync encoded in differential common mode. R2-R3, R4-R5 and R7-R8 resistors provide impedance matching with the twisted pair cable (TP). Because we deal with both positive and negative sync polarities, a special block consisting in hex inverting Schmitt triggers[4] (74HC14) and 3 digitally controlled analog switches were introduced on sync lines. When Hsync has negative polarity, U4F output becomes high and it charges C9 capacitor through R15. At that moment of time, A selection input of U3 changes its state in H and selects X₁ input. X₁ is driven by U4D inverter, which outputs a positive polarity Hsync.

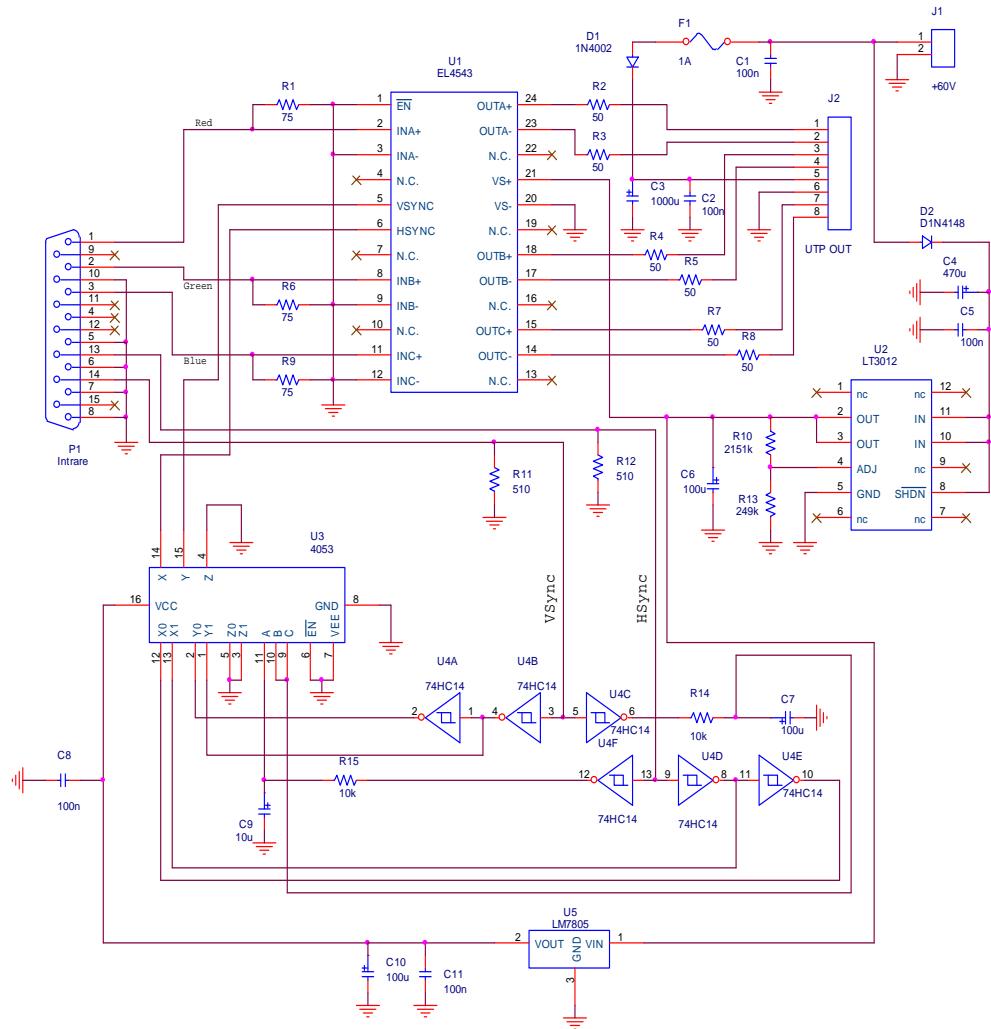


Fig. 5 XGA/TP converter

In the situation when input Hsync signal has positive polarity, A selection input remains low and selects X_0 input. X_0 is driven by U4E and U4D cascaded inverters. Output signal will always remain with positive polarity. The same situation happens with Vsync signal. In table 1 we present the status of selected channels as a function of sync signals polarity.

U2 is a programmable, high voltage, micropower low dropout linear regulator which fulfils U1 power supply. Output voltage is set with R10-R13 resistors:

$$V_{out} = 1.245 \cdot \left(1 + \frac{R_{10}}{R_{13}} \right) + I_{ADJ} \cdot R_{10} \simeq 12V \quad (8)$$

Table 1

Sync signals polarity

Case	Input states		ON Channels	Input sync signals Polarity		Output sync signals Polarity
	A selection input	B,C selection inputs		Vsync	Hsync	
1	L	L	Y=Y ₀ X=X ₀	Positive	Positive	always positive
2	H	L		Positive	negative	
3	L	H		Negative	Positive	
4	H	H		Negative	Negative	

4. TP/XGA converter

Situated inside receiver module, its main functions are to obtain R, G, B and sync signals recovery and to do phantom power supply. A single channel differential receiver and equalizer is used for each primary color extraction (U1, U4, U5) [5]. As TP cable attenuation characteristic depends on cable length, two adjusting circuits were introduced. First circuit sets the gain control voltage to compensate for any loss errors that affect the contrast of the video signal. The signal may be trimmed up or down by 6dB, in the ratio 4:1. Because cable frequency response is not a linear function (high frequency information is attenuated more significantly than the information at low frequencies) a second circuit with a selective gain adjustment is placed.

Video signals are received in differential mode using AC coupling. Hsync is extracted from common mode output voltages difference of Red (U1) and Blue (U5) receivers:

$$U_{outHsync} = V_{CMR} - V_{CMB} \quad (9)$$

Then it's passed through two-cascaded Schmitt triggers to eliminate unwanted signal transitions, and applied through a 75Ω impedance matching resistor to the output.

Vsync is extracted in the same manner, with the mention that all common mode output voltages of Red (U1), Green (U4) and blue (U5) receivers are present in the equation:

$$U_{outVsync} = V_{CMR} + V_{CMB} - V_{CMG} \quad (10)$$

Note that U2A differential inputs are connected through a RC low pass filter used to clear the high frequency noise.

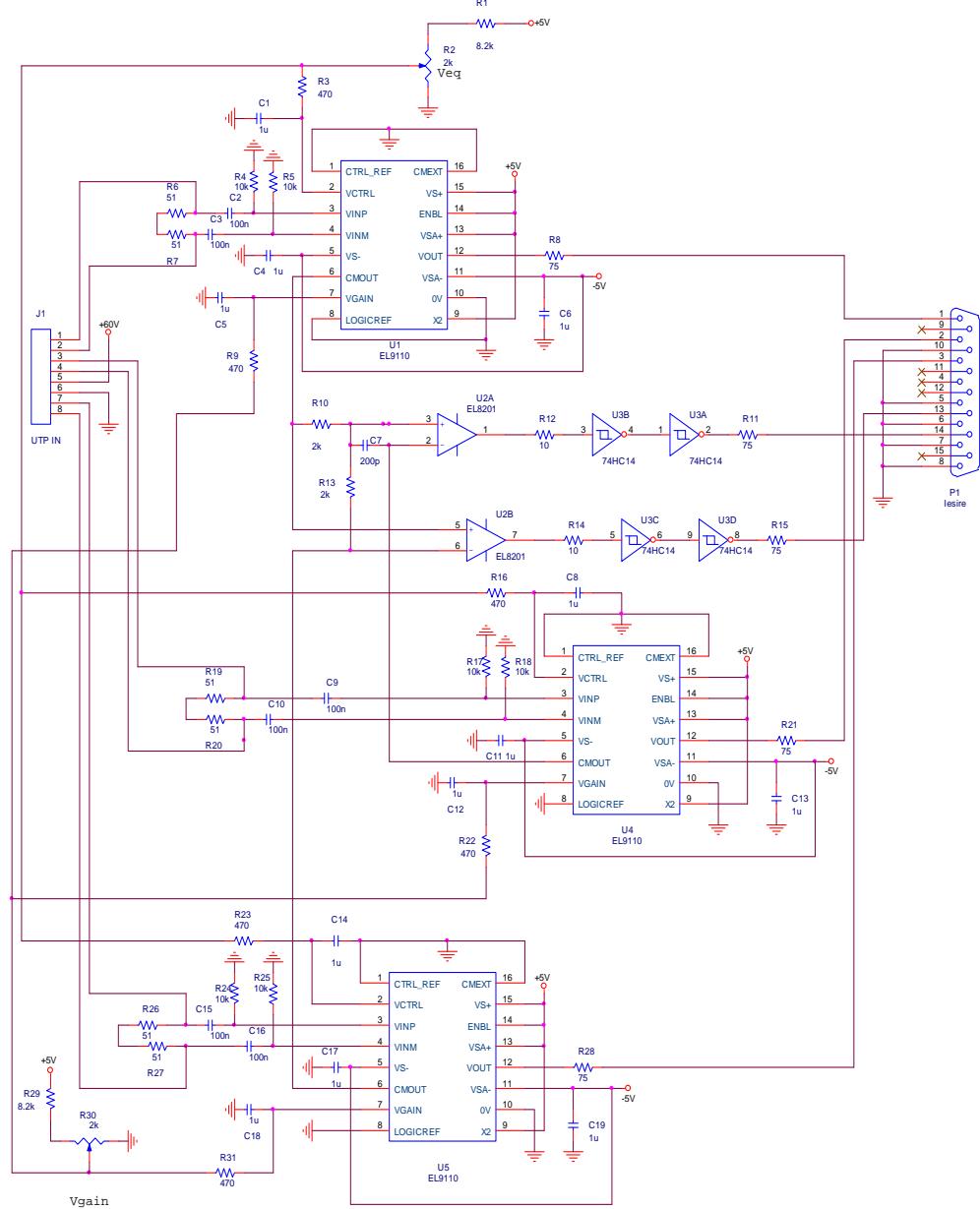


Fig. 6.TP/XGA converter

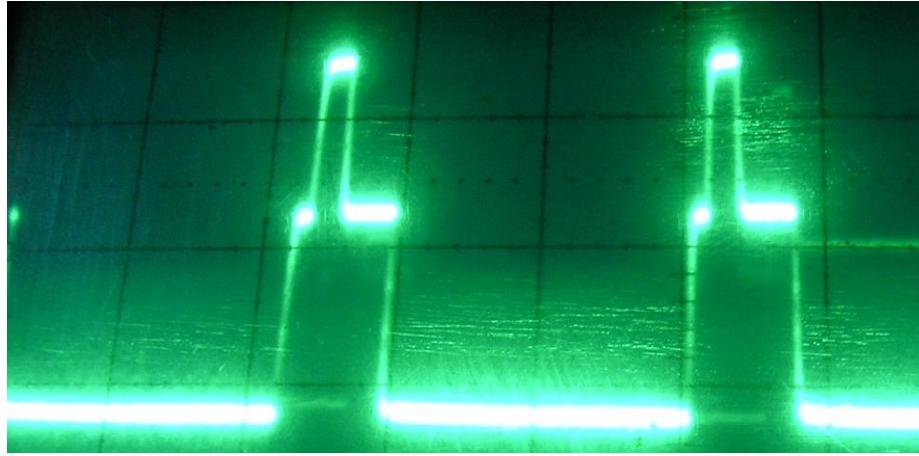


Fig. 7 Red+Sync signals on TP cable (a red image is applied from XGA pattern generator)

The phantom power voltage is dropped to a +12V value with a high efficiency (90%) step-down converter [6] which supplies all circuits inside receiver box. Delivered output current may overtake 3A when LCD's backlight dimming is at maximum value. The step down switching regulator controller uses constant on-time valley current control architecture to deliver low duty cycles with accurate cycle-by-cycle current limit, without requiring a sense resistor. U01 IC is optimized to drive a power N-channel MOSFET current amplifier pair in a rectified buck converter topology. Output voltage is set by R03 and R04 feedback network. L03 value is critical when a high efficiency is required.

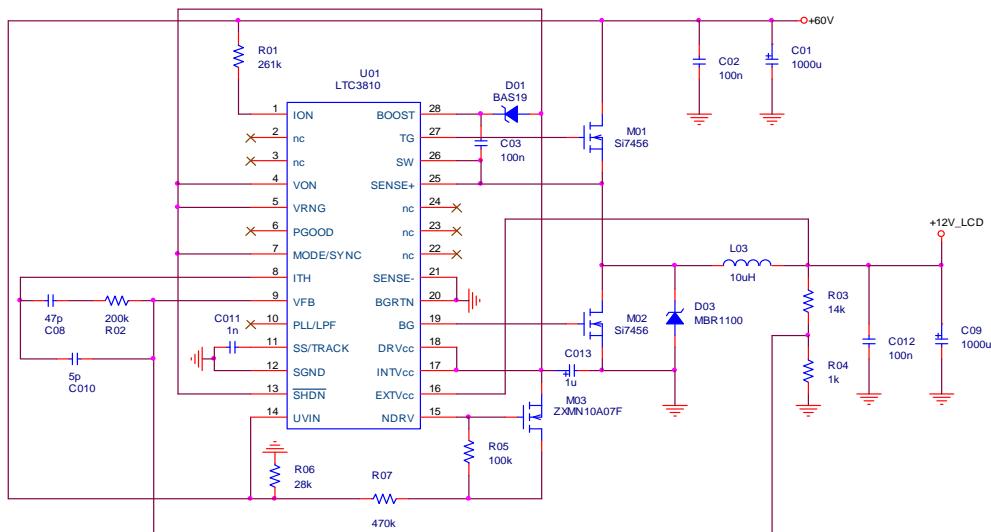


Fig. 8 Phantom power converter

For TP/XGA converter circuits, a $\pm 5V$ voltage supply is made through two simple current mode DC/DC controllers capable of driving currents up to 175mA with 90% efficiency.

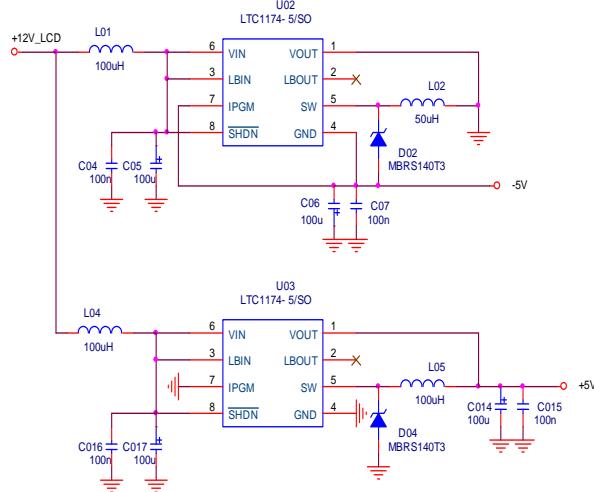


Fig. 9 TP/XGA power supply circuit

5. XGA 1:2 converter

This unit has the same construction as XGA 1:3 converter and there's no need of further discussion.

6. Liquid crystal display module (LCD)

LCD module [7] is a low-power-high-brightness unit, which should offer vibration resistance and wide operation temperatures. It includes: a XGA resolution LCD panel with LED backlight and TCON module, one power inverter, a LCD controller board, one touchscreen controller with RF interface and electromagnetic pen (optional) and a power supply unit.

The analog signal is applied through VGA port to LCD controller board. A dedicated mixed signal programmable interface video controller converts the analog signal to digital format and scales it to LCD native resolution (1024x768). The board will output video signal as digital information through a low-voltage differential signaling (LVDS) interface. External serial flash memory stores informations about LCD panel type, inverter, keyboard commands and OSD language. One programming interface permits firmware updates for internal flash memory of the video controller. TCON board (timing control board) handles data time multiplexing and power supply for each pixel inside LCD matrix. Inverter

will supply light-emitting diodes (LED's) with a programmed variable voltage, depending on ambient light intensity captured by photoresistor (light dependent resistor) or user settings (backlight dimming). Inverter output voltage should not exceed 48V.

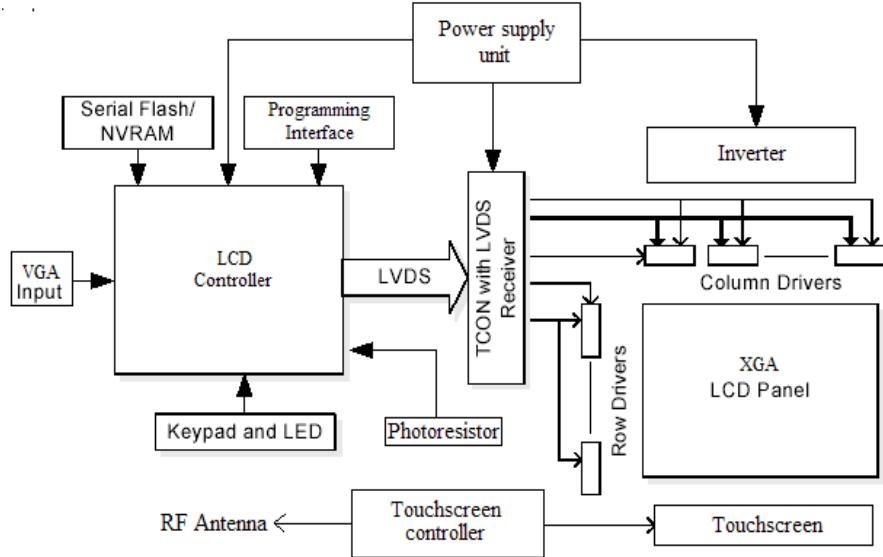


Fig.10 LCD controller

For human easy operation in harsh environments, LCD module is equipped with an attached touchscreen. The touchscreen module is a RF type and it will send commands from human operator to a remote computer located outside dangerous environment. A battery free electromagnetic pen permits mouse operations on graphical user interface (GUI).

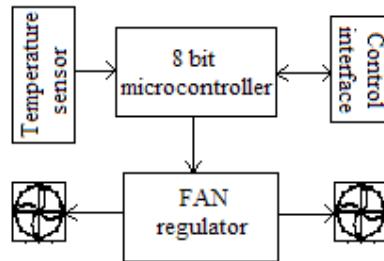


Fig. 11 Cooling system

Cooling system maintains a temperature below 40°C inside receiver box and shuts down the system if temperature exceeds 60°C . A digital temperature sensor sends temperature measurements to the 8 bit microcontroller[8], which computes its DAC's (digital to analog converter) value to be sent to the FAN

regulator. This regulator is a simple DC power amplifier used for direct drive FAN motor. FAN speed depends on ambient temperature. If inside temperature is below 25°C, the microcontroller will stop the cooling fans. Control interface permits an easy communication with LCD controller and microcontroller flash programming in the field.

7. Conclusions

A digital signage equipment destined to be used on gas station pumps has been designed and tested. Special safety measures were took into account because of the high risk degree of the place where is mounted the equipment: low supply voltages were applied to the circuits, all the electronic boards and displays were completely isolated from surrounding atmosphere by introducing them in an aluminium box with a special cable gland, boards with supply voltages greater than 12V were immersed in epoxy resin. The equipment meets IP65 standard specifications for fuel dispensers. Compared to another classic equipments (Hyundai H2010, T2010) which are using separate cables for power supply and signal transmission, only one twisted pair cable supplies the box and carries video information up to XGA resolution. Meanwhile commercial equipments use main AC for box power supply (T2010, H2010), this design uses a phantom power technique for safety reasons to avoid electrical discharge and fire. Cooling system permits continous operation in sunlight. The distance between source signal and the box may be extended up to 60m without affecting image quality. A RF touchscreen have been used for easy communication between the operator and the base station. During prototyping, all boards were introduced inside a furnace with precise temperature control function to assure and verify operation between 40°C and 70°C.

R E F E R E N C E S

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