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Microcontroller Peripheral Mapping Used to Control RGB LED Panel

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Abstract: Big graphical screens are becoming more common as their prices have significantly dropped in the recent years, providing advertisements, traffic information, timetables, navigation, and other information services. This paper describes a construction of a cheap alternative to the expensive commercial products.
This paper provides a technical solution for a low-resolution panel based on strips containing WS2801 PWM controller and 5050 RGB LEDs. The encountered implementation problems are discussed, and unique features of the PIC18F26J50 microcontroller are used to control the panel.

Keywords: Microcomputer, Microprocessor, Output Signals, Signal Levels, Displays, Impedance Control, Crosstalk, Communication Channels

1. INTRODUCTION

Big graphical screens are becoming more and more common as their prices significantly dropped in the recent years. They are used not only for advertisements, but also for providing traffic information, timetables, navigation, etc. With the widespread use of cheap components, electronic enthusiast have attempted to create cheap versions of the expensive commercial products. This paper discusses the practical issues of creating a large graphical screen based on the generally available parts. The motivation was to give a general overview of all construction aspects and limits that are usually neglected in small constructions published by electronic hobbyist. The secondary motivation was to create a usable screen for demonstration purposes.

Our department required a big advertising screen for university propagation on many public events. The requirements for the screen were:

- lightweight construction for indoor usage only,
- dimensions approximately 2×1 m,
- easy transportable and flexible,
- reasonable price,
- and not demanding high resolution.

The majority of the large screens are nowadays based on the RGB LED technology. In the Czech Republic, there are only a few manufacturers developing and producing this type of products. One of the best known manufacturers is *Reklamni obrazovky* [1]. The manufacturer website offers customers an online tool to calculate the price according their requirements. The calculated prices of the advertising screen suitable to our requirements started at \$12000. The offers of the rival companies are in similar price range. Because the price is comparable with a new small car, it was not acceptable for our department. Thus we have decided to find a viable way to construct similar large screen by ourselves.

2. DESIGN OF RGB LED PANEL

The usual construction of advertising screens is based on the wire matrix. Horizontal and vertical outlines are perpendicular to each other, with a single LED mounted in each intersection. However, this construction is not suitable for our case, as we have required a flexible construction.

There is one, not very well known, technical solution available on the market suitable for the flexible LED panel. Several companies produce special RGB LED strips with PWM controller. Every cell contains an RGB LED (type 5050) coupled with a PWM controller WS2801. The PWM controller is controlled by a serial line.

2.1 RGB LED Panel Proposal

The size of a single cell in the strip we have used is 31.25 mm. Thus one meter of the strip contains 32 LEDs. For 2 meters wide panel we will be using 2 meters of the strip, so each row on the panel will contain 64 LEDs. The height of the panel depends on the vertical resolution. The normal aspect ratio of the screen width and height is nowadays 16:9. When the width of the panel is 64 LED, the height should be 36 rows. The resolution of the proposed screen is 64×36 LEDs and for the whole panel we will require 72 m of the strip.

Because the serial line passes through the whole strip, it is possible to connect more strips serially to one long chain. Thus the panel can be designed as a single long chain,

[1] `http://www.reklamniobrazovky.cz`

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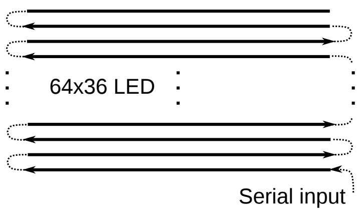

Fig. 1. Multirow strip connected to the single serial line

interconnected in a zigzag fashion over the whole height as shown in Figure 1.

The market price of one meter of the strip is around $12 (Q1 2015). The expected price for the whole panel is $864. It is significantly less than the price of the commercial panels. Low price, however, is compensated by the larger distance between LEDs and consequently low resolution. The strip is flexible enough and it can be easily mounted on a flexible backing such as linoleum or rubber.

2.2 RGB LED Panel Technical Parameters

The two most important parameters of the proposed RGB LED panel are the power consumption and refresh rate of the whole panel. The refresh rate will require corresponding speed of the serial line to control PWM controllers.

The RGB LED 5050 is produced by many manufacturers and every LED has almost the same technical parameters. We have selected IWS-L5056-RGB-K3 (the datasheet is available at Itswell (2012)). The current for each color is typically around 30 mA. On the strip the current is reduced by resistors to 25 mA per color.

The WS2801 PWM controller datasheet is available at Worldsemi (2008). The typical supply current for this controller is 1 mA. As we now know all important parameters, we can compute the required current for a single row of the panel using Formula (1).

$$I_{row} = (I_R + I_G + I_B + I_{WS}) \cdot W \tag{1}$$
$$= (0.025 + 0.025 + 0.025 + 0.001).64 = 4.864 \quad [\text{A}].$$

In Formula (1) the current for individual colors is marked as I_R, I_G and I_B. The supply current for the PWM controller is I_{WS} and W is the number of cells in the single row. The whole supply current for one row is I_{row}.

The current I_{row} is the maximum current when all LEDs are saturated to the maximum power. In the normal situation the supply current is significantly lower. The maximum current required for the whole panel is computed from the current I_{row} and from the number of rows H in Formula (2).

$$I_{all} = I_{row} \cdot H = 4.864 \cdot 36 = 175.1 \quad [\text{A}]. \tag{2}$$

The supply voltage for the strip is 5 V and based on this we can compute the total power supply using formula (3).

$$P_{all} = I_{all} \cdot U = 175.1 \cdot 5 = 875.5 \quad [\text{W}]. \tag{3}$$

To provide sufficient power, we need two 5 V/500 W power supplies. The important limitation of the RGB LED panel is the serial line speed. The WS2801 chip is controlled by a synchronous two-wire serial interface. One wire is used for the clock signal and the second wire is used as the data line. This serial interface is compatible with the well known SPI interface which uses 3 wires: clock, data input and data output. The WS2801 does not use data output, so it is not present.

The WS2801 requires 3 bytes to set PWM level for each of the three base colors, i.e. each color value is specified by 8 bits. The following data block on the serial line is forwarded to next chip on the strip. The short idle of clock signal resets the WS2801 and a new data is then accepted by the chip again. This short idle is defined in the documentation as $t_{res} = 0.5$ ms. Therefore, it is possible to easily calculate how many bits are necessary to be send to all chips.

$$B_{all} = W \cdot H \cdot 3 \cdot 8 = 64 \cdot 36 \cdot 3 \cdot 8 = 55296 \quad [\text{bits}]. \tag{4}$$

In Formula (4) we have computed the number of bits for all LEDs to display one static image. Because data are transferred by the serial line, the number of bits is equal to the number of clock pulses required to synchronize the data transfer.

Now it is possible to compute the required speed for the serial line and the given refresh rate. We require the refresh rate $f_{ref} = 25$ Hz. By using this rate and known number of bits per one image we can compute the required maximum serial clock rate, see Formula (5).

$$f_{max} = \frac{B_{all} \cdot f_{ref}}{1 - t_{res} \cdot f_{ref}} = \frac{B_{all}}{\frac{1}{f_{ref}} - t_{res}}$$
$$= \frac{55296}{\frac{1}{25} - 0.0005} = 1399899 \quad [\text{Hz}] \tag{5}$$

The maximum clock rate allowed by the WS2801 controller is according to the datasheet $f_{limit} = 25$ MHz. The required rate computed in Formula (5) is significantly lower than the operating limit of the WS2801 controller.

2.3 Problem of the WS2801 Controller

According to the previous section and theoretical assumptions we have bought 72 m of the LED strip. Before the whole strip was mounted on the backing, we have tested only a short, 20 m long chain. For this chain, we have tested the maximum serial line clock rate needed to reliably control all LEDs in the chain.

The behaviour of the WS2801 brought one annoying surprise. When the serial line clock rate has been increased, the number of controlled LEDs in the chain has decreased. With 4 MHz clock rate it was not possible to control more than 6 meters of the LED chain (i.e. 192 LEDs).

To diagnose this problem we have connected a digital oscilloscope to the signal wires of the chain. In Figure 2a we can see the input signal at first chip in the chain. The channel 1 is the clock signal and the channel 2 is the data signal. The data clock was set to 4 MHz and in Figure 2a,