Simulation of Signals in Digital Television Using LabVIEW

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***Abstract**: This paper presents an application for generating of all the signals in case of digital televisions corresponding to standard colour bar patterns, from primary RGB signals to YCbCr colour space digital signals. It was implemented in LabVIEW and can represents D1 and D2 format for DTV signals on 8 and 10 bits resolution. The application can be used for DTV signals teaching and analysing in case of different image patterns.*

1. INTRODUCTION

Digital television (DTV) and digital cameras gradually replaces the analogue television [1]. These systems use digital signals for transmission, instead of classical analogue signals in analogue TV [2], [3]. Generating DTV signals for certain types of image patterns is very important in teaching activities for understanding the DTV principle, as well as for analysing and testing of certain circuits from TV sets. Simulation of these circuits becomes eloquent only if specific TV signals are applied. Such specific signal sources do not exist in libraries of commonly used circuit simulators, so we must generate these TV signals.

2. SIGNALS IN TV DIGITAL

The color space YCbCr was developed as recommendation of ITU Recommendations BT. 601 or ITU-Rec601 (the old CCIR601) for digital television, as an offset scaled variant of YUV color space [4], [5].

$$Y=0.299\cdot R+0.587\cdot G+0.114\cdot B \qquad (1)$$

$$C_R=\frac{0.5}{0.701}(R-Y)=0.500\cdot R-0.419\cdot G-0.081\cdot B$$

$$C_B=\frac{0,5}{0.886}(B-Y)=-0.169\cdot R-0.331\cdot G+0.500\cdot B$$

According to ITU-Rec 601, digital component signals $\overline{Y},\overline{C}_R,\overline{C}_B$ are obtaining by analog-to-digital conversion of *Y, C_R, C_B* signals. There are different digital formats called D1, D2, D3, D5, D6, etc.

The conversion standard 4:2:2for D1 uses 13.5MHz sampling frequency for luminance signal Y and 6.75 MHz sampling frequency for *C_R, C_B* signals, which results in 720 samples for Y and 360 samples for $\overline{C}_R,\overline{C}_B$. The correspondence between *Y, C_R, C_B* and $\overline{Y},\overline{C}_R,\overline{C}_B$ signals is represented in figure 1.

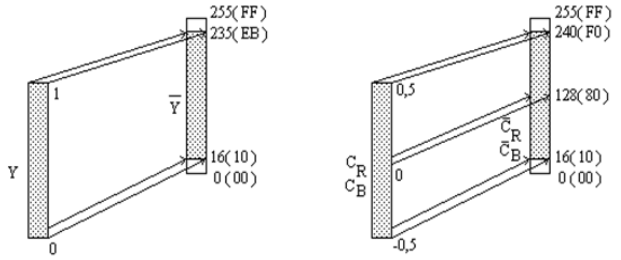

Fig. 1. Correspondence between *Y, C_R, C_B* and $\overline{Y},\overline{C}_R,\overline{C}_B$

From figure 1 results that:

$$\begin{aligned}\overline{Y}&=219Y+16\\ \overline{C}_R&=224C_R+128\\ \overline{C}_B&=224C_B+128\end{aligned} \qquad (2)$$

The signals conversion correspondence in case of D1 standard is represented in figure 2.

Because D1 standard lead to a 27MB/s data transmission rate, another format, D2, was developed as a low cost alternative to D1 format.

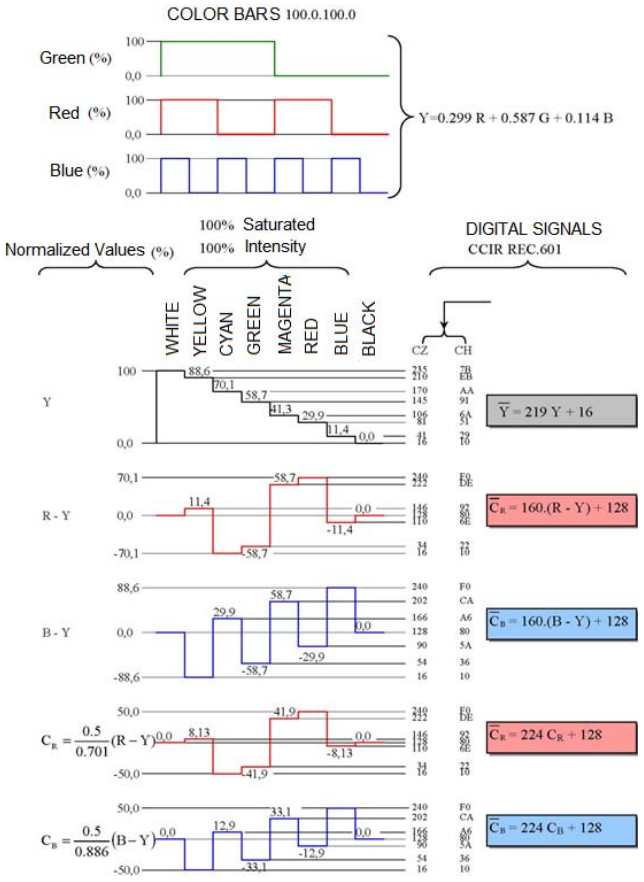

Fig. 2. D1 signals with 8 bits resolution, according to CCIR Rec.601

D2 format converts the PAL/NTSC composite TV signal at a sample rate at four-time-color-subcarrier 14.318MHz. This standard reduces the transmission data rate.

The other digital formats are used for high definition television or for professional high definition video recorders. D5 HD format can achieve 720 progressive lines and 1080 interleaved line at 60 Hz and D6 HDTV format supports 1900x1080 image resolution [6].

3. Simulation of D1 and D2 DTV Signals in LabVIEW

The application for DTV signal generating was developed in LabVIEW, as a teaching and training tool. It presents all signal construction, from primary RGB signals to output digital signals. The DTV signals were simulated in case of color bars test pattern, for D1 and D2 formats with 8 and 10 bits resolution.

The primary RGB signals can be generated for different patterns by analyzing the combinations needed in case of different colors, starting form standard color bar pattern.

Another possibility is to extract the RGB components from a given image pattern, using image decomposing techniques, called color plane extraction (RGB plane). This is realized in the application by using image processing functions from Vision. The color bars pattern decomposition in RGB images and the LabVIEW code is presented in figure 3 a) and b).

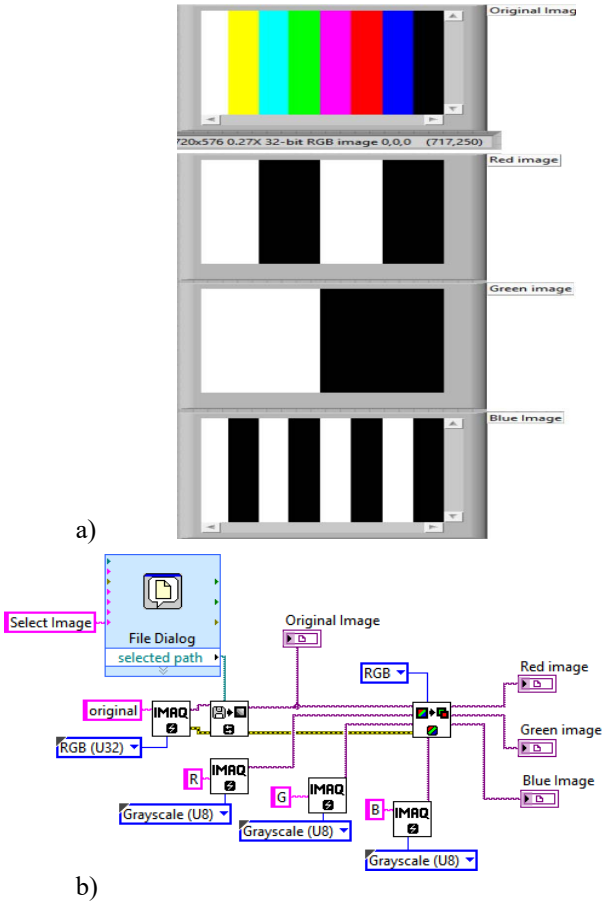

Fig. 3. Color bars pattern decomposition in R, G, and B monochrome images: (a) R G B images; (b) LabVIEW code

The LabVIEW code (block diagram) for generating of DTV signals in D1 format is presented in fig. 4 and the obtained signals are presented in fig.5. The signals for D2 format are represented in figures 6 and 7.

Primary signals for different image pattern can be generated by user in generating E_R, E_G, E_B signals block. The corresponding primary signals can be also extracted from given image read from a file or live, from camera, by replacing the signal generating block with image reading block.

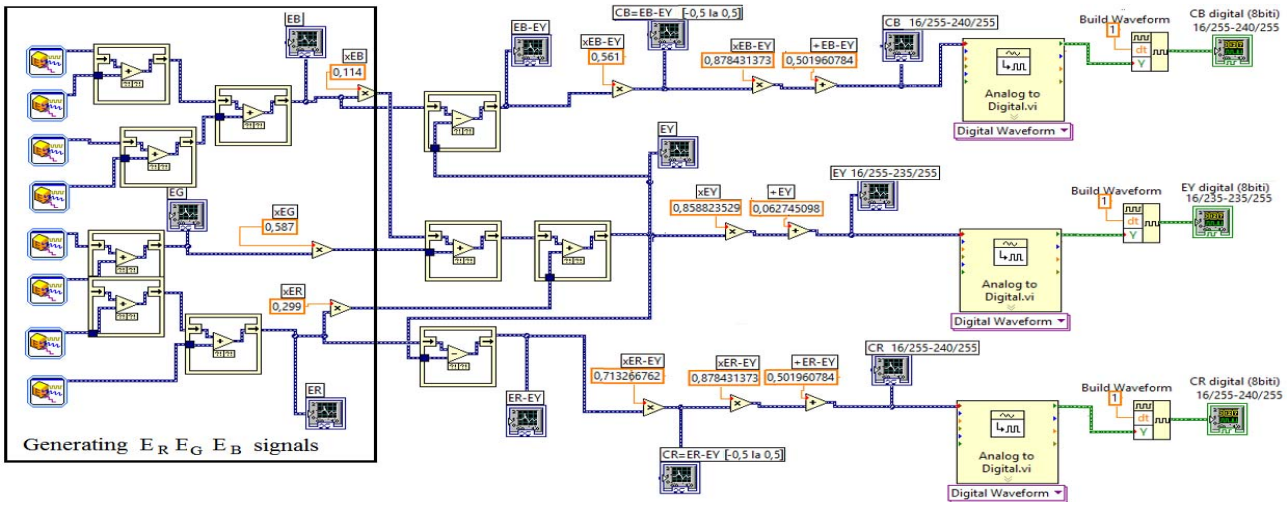

Fig. 4. LabVIEW code for generating of digital TV signals in D1 format, for colour bars test pattern.

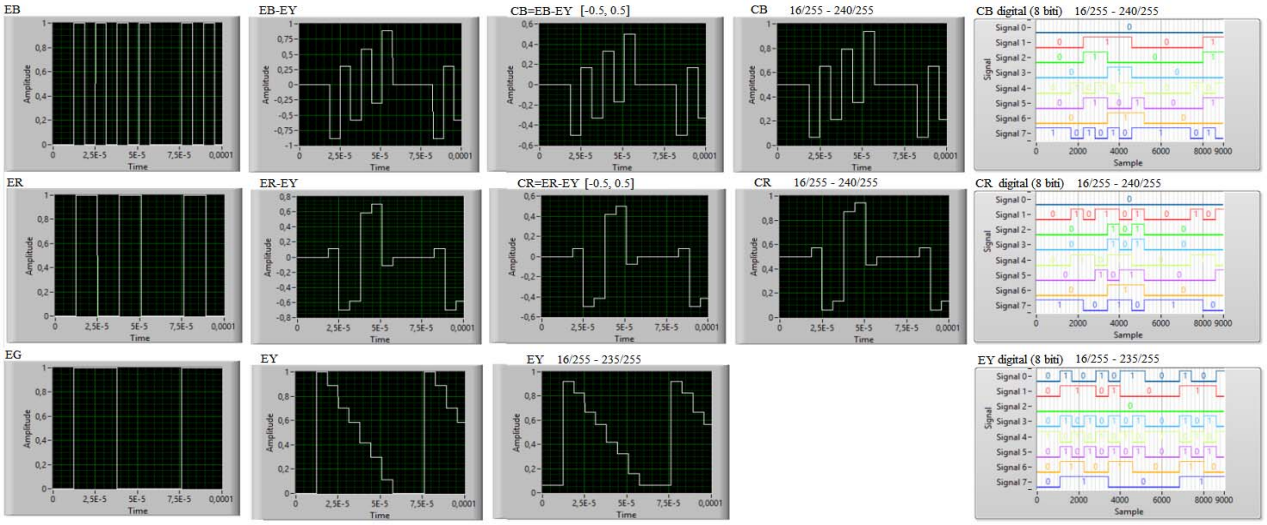

Fig. 5. Simulation in LabVIEW of digital TV signals in D1 format with 8 bits resolution, for colour bars test pattern.

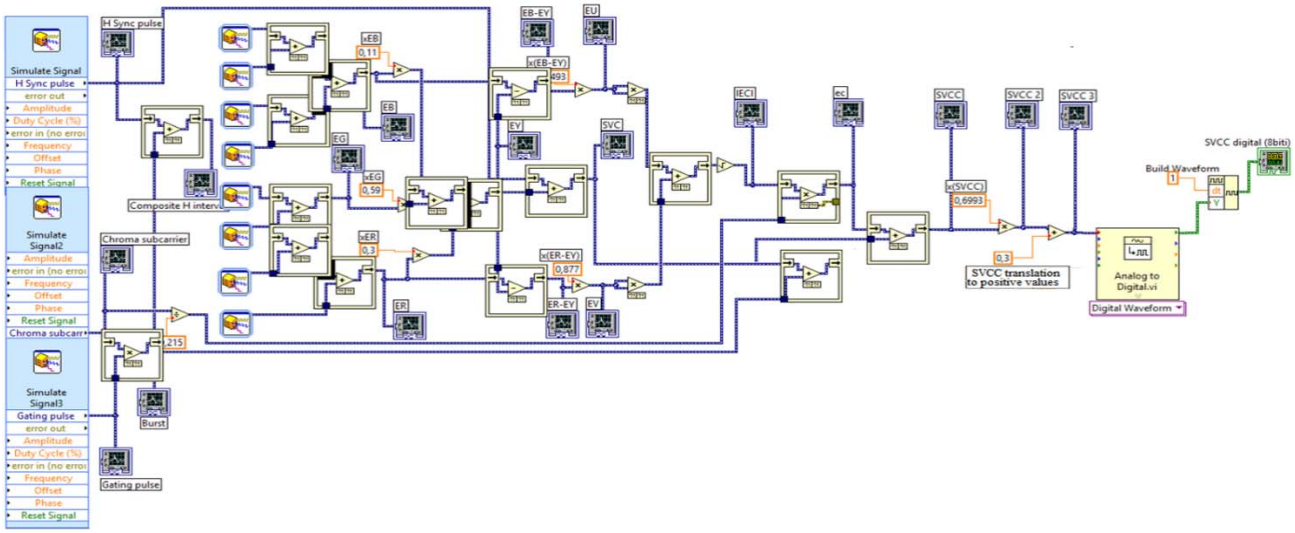

Fig. 6. LabVIEW code for generating of digital TV signals in D2 format, for colour bars test pattern.

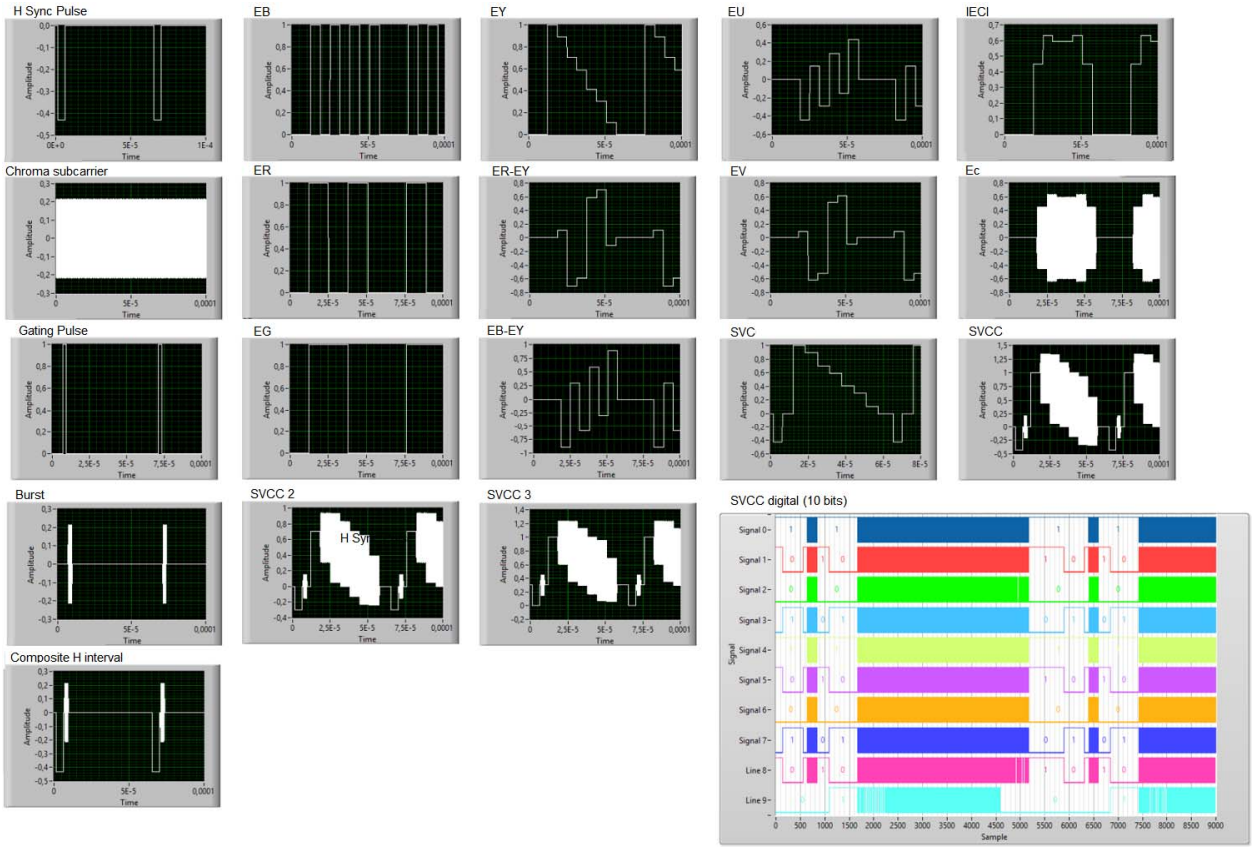

Fig. 7. Simulation in LabVIEW of digital TV signals in D2 format with 10 bits resolution, for colour bars test pattern.

The obtained DTV signal can be generated at an output port for measurement and testing of real circuits, using proper hardware. Figure 8 presented a hardware module implementation for generating the DTV signals, using the microcontroller PIC24EP512GU810 and EasyTFT colour TFT touchscreen.

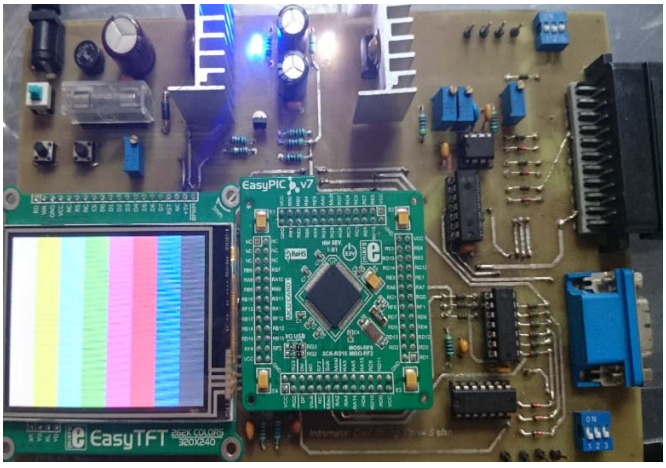

Fig. 8. Hardware module for generating the DTV signals.

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