COMPATIBLE COLOUR NBTV on CD (CCNC)

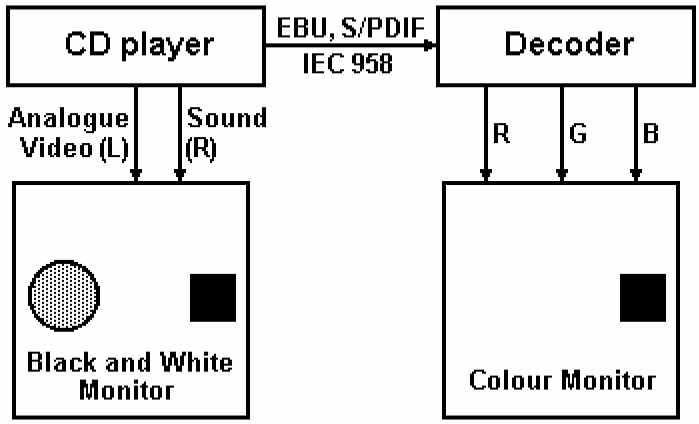
by Klaas Robers and Vic Brown

Colour NBTV seems to be becoming very popular. After Vic Brown showed this at the 2004 Convention more members built an RGB LED-array to convert their B+W Nipkow monitor into a colour monitor. The changes are not too radical, and the enhanced viewing experience makes it an attractive idea.

The signal source

For RGB colour we need three video signals. When coming directly from a camera or some other NBTV source this is not a problem, but we want to store and replay them as well. Initially, Vic did this on CD-R by splitting up the 32-bits CD-samples (2 channels, 16 bits wide) into four 8-bits words (RGB + Sound). A CD-ROM player played the disc and some dedicated electronics recovered the four separate bytes. This works very well, however a CD made in this way can't be played as a B+W club-CD

The question came up: "Can we record a CD in such a way that it can be played as if it was a B+W disc, giving good rendering of colours in black and white, as well as in full colour using special decoder electronics?" This decoder could be connected to the digital audio output (EBU code) of the CD player (see diagram). Then we arrive at a situation comparable to the introduction of compatible PAL-NTSC-SECAM colour TV. Sound can also be recorded in the normal manner, whereas the 4-channel 8-bits system left only 8-bits for a reduced quality sound channel.



Where to find the bit space

For such a compatible system we shouldn't use the sound channel, so only the left-channel stream is available to store the RGB video. Furthermore, this channel should still be producing a B+W NBTV signal, so the possibilities are very limited. The only viable option came from the fact that for an NBTV video signal there is no need to use 16 bits of quantisation. From the CCIR TV system we know that for black and white six bits (64 levels) are almost sufficient if sync is not enclosed; including sync 7 bits are needed. If PAL colour is present, i.e. a CVBS signal, we need 8 bits. This also applies, more or less, to NBTV signals. So we have identified bits in the lower part of the left CD-channel free to encode the colour information. In doing so, this results in small noise-like variations in the analogue B+W video signal, so small that we don't observe them.

In the B+W Compact Disc club standard we use only a certain part of the available voltage range of CD. The luminance part of the signal, i.e. black to white, has an amplitude of 1 volt peak to peak, while the maximum output of the CD-system is 5.6 volts peak to peak. There is also sync, of course, but even then we use no more than ¼ of the available range. This leads us to a choice of the 9 most significant bits for a luminance signal (Y), of which the 2 most significant bits are effectively not in use. Then the 7 least significant bits are free to encode the colour (C).

Y8	Y7	Y6	Y5	Y4	Y3	Y2	Y1	Y0	C6	C5	C4	C3	C2	C1	C0

Matrixing for Y

First we need to make a luminance (Black and White) signal from Red Green and Blue signals. This is not so difficult in a computer program, but we have to decode it again in hardware (using simple digital electronics) during play back. So the calculations should not be too complicated and for this reason we took very simple rules of calculation. Starting from Red Green and Blue having digital values in the computer of 0 (00) for black to 255 (FF) for maximum we calculate the luminance signal as: **Y = R/8 + G/4 + B/16**. Now the Y signal has a minimum of zero (00) for black and a maximum of 111 (6F) for white. This fits easily in the bits Y6 ... Y0, leaving bits Y8 and Y7 zero. This gives us an analogue video signal of 1.2 volts Black to White, not too far from the original 1 volt. A small adjustment of the contrast setting on a B+W monitor will compensate for this. The sync pulse level will be – 48 (1D0) for a sync/video ratio of 3/7.

Colour encoding

After quite a lot of discussions we chose to encode Red and Blue in the bits C6 ... C0 in a sample sequential way. Both signals are concatenated to 7 bits, 00 to 127 (7F). The even samples are used for **Red** and the odd samples for **Blue**. Because the sample frequency of CD is quite high this gives a colour bandwidth of about 10 kHz, almost equal to the maximum resolvable B+W bandwidth of a 32 line Nipkow disc monitor. During our discussions we called this the Alternating Red and Blue signal, ARB. At play back we can separate the Red and Blue samples, and recalculate the Green signal in this way: **G = 2Y - R/2 - B/4**. This gives also a 7-bits number and can be easily performed by shifting, inverting and adding.

During sync, i.e. when bit Y8 is one, the ARB channel is encoded as **04** for the Blue phase and **03** for the Red phase. It can be regarded as an ARB burst. This defines the ARB phase for the decoder, but it indicates as well that we have a colour signal. During a colour video signal the RB alternation always is continued, also during sync. This requires some encoding effort, because an NBTV-line has a precise duration of 110¼ CD-samples. A decoder might switch over temporarily to B+W when there is a hiccup in the ARB phase.

Limitations and results

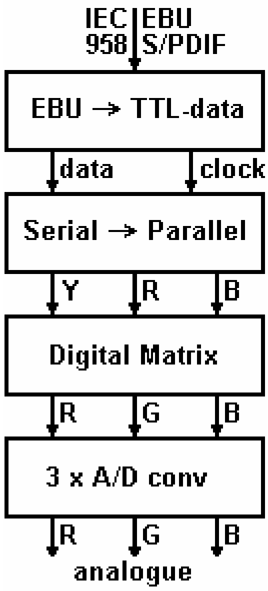
Because the Y signal and the ARB signal are bound to exact bit positions everything is disturbed when we fade the video by (digital) attenuation. Just like SECAM we can't edit the signals by making fades. This limits the possibilities. However it is very easy in a computer program to convert the composite Y-ARB signal temporarily into separate Y and ARB signals and store the ARB signal multiplied by 128 in the right channel. Then we can fade and edit the channels together. Having done that we can combine them again into the left channel and restore the sound on the right channel.

Klaas and Vic did quite a number of experiments with stills and video processing in Basic (fast programming and slow running, but who cares?) and an experimental digital decoder. This demonstrated that the colour picture quality is hardly distinguishable from four full-bandwidth channels of 8 bits. Moreover the B+W video signals are perfect, with not the slightest signs of the extra colour information contained in the signal. This was mainly done using stills, because they are easier to observe carefully.

This is, of course, a CD-only system. We exploit the larger precision of the 16-bit CD channel and we use the higher sampling rate of CD, higher than the NBTV signal needs. One-to-one copying from a CD player to a CD-R recorder is unlikely to succeed owing to unwanted signal conditioning and format conversion during the transfer process. However, copying from a CD player to a CD recorder via a digital audio interface should be possible. It also looks unlikely that the analogue output of a CD-player could be used to extract the colour information. In other words, the colour decoding must be done in the digital domain.

Decoder

A digital colour decoder should be connected to the digital audio output of your standard CD-player. This output is referred to as EBU, IEC958 or S/PDIF. It can be a coaxial cable connector or an optical fibre connection. The decoder accepts these signals, converts them into a parallel data stream, some simple digital circuits split Y, R and B, recalculate G and convert digital to analogue, thus regaining the R G B signals.



We hoped to have a decoder circuit available and a PCB designed to facilitate building a decoder, but we encountered a practical problem. Vic used the integrated circuit CS8412 in his experimental design for a decoder, which was used to test the system. This chip, which converts the EBU signal into a clocked digital data stream, became obsolete. Only recently Vic found a similar chip CS 8416 available from some suppliers. It had been tested and looks suitable, however this is a surface mounted chip (SMD), making building yourself less convenient. Some more problems have to be solved before we arrive at a finalised design, e.g. how to show black and white CD's through the digital decoder.

Alongside the decoder we hope to make a Club CD with CCNC video. For stills this is not a great problem, but moving video is much more difficult, especially if you want to include lip-sync sound. If other members have good ideas on how to produce and decode CDs using this format we would be very interested. Wait and see. It is remarkable to see that our Club generates scientific developments in the old mechanical TV system, developments that were roughly cut by the coming of the all-electronic system.