

SYNCHRONISATION OF TWO CAMCORDERS WITH PI CONTROLLER – 3D LANC MASTER

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Abstract: A device, which keeps two camcorders permanently in synchronisation, has been developed. The mentioned device uses LANC (CONTROL-L) camcorder's inputs for synchronisation. It enables controlling of two camcorders simultaneously via built-in buttons, by using external LANC remote controller and/or by the PC via serial (RS232) communication. Since device requires LANC inputs on camcorders (or still cameras), it can be used on some camcorders produced by manufacturers Sony and Canon or some still cameras produced by Sony. Permanent synchronisation can be achieved only on some camcorders produced by Sony. The effectiveness of the proposed device is demonstrated by several experiments.

Keywords: stereoscopy, camcorder, PI controller, synchronization.

1. INTRODUCTION

Stereo (3D) photography is almost as old as classical photography, since the first stereoscopic camera with two lenses was made in 1849. The first stereoscopic film was made by brothers Lumière in 1903. Popularity of stereoscopy had risen until the 1950s, when CinemaScope wide-angle format won over the stereoscopic films, mainly due to reduced production costs and higher quality. Today stereoscopic video cameras are again gaining in popularity due to cheaper ways of producing and showing stereoscopic content. The stereoscopy is mostly used in geodesy, medicine, chemistry and in entertainment industry. However, amateur stereoscopic video maker is still faced with relatively high costs of stereoscopic video equipment. One of the main requirements for making stereoscopic videos is that both camcorders are tightly synchronised. Such synchronisation is required in order to correctly fuse left and right pictures of the moving objects into one stereoscopic (3D) picture.

Figure 1 depicts the case when an object is moving horizontally. If the cameras are not synchronised (right picture is taken some time interval after the left one), the right picture of the object is taken at position b instead of a so the fused (stereoscopic) image is created in incorrect position d instead of c . The fused stereoscopic picture therefore appears righter and closer than in reality. The second case is when the object is moving vertically (see Figure 2). Due to non-ideal synchronisation, the right picture is taken in position b instead of a . In this case the stereoscopic picture cannot be fused at all. There appears double picture d instead of one stereoscopic picture c .

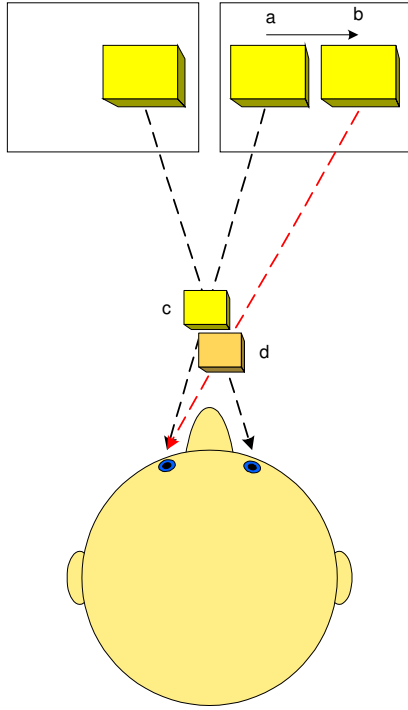


Fig. 1. Horizontal displacement due to shooting time difference

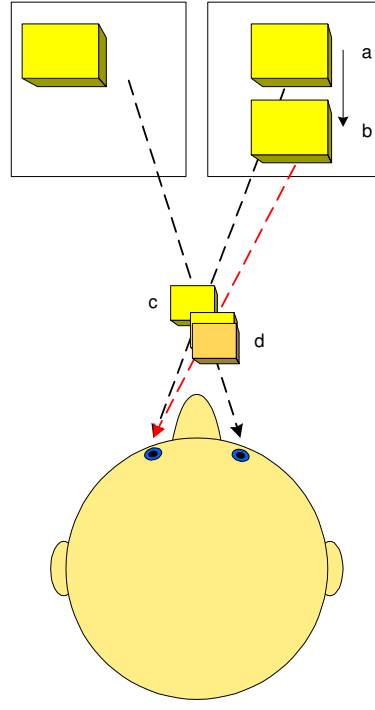


Fig. 2. Vertical displacement due to shooting time difference

Accurate synchronization of camcorders (or still cameras) is therefore very important in stereoscopy. Precise synchronisation can be achieved by using some professional video camcorders which are equipped with connectors dedicated for synchronisation. However, those inputs are not available in consumer video equipment, so taking quality stereoscopic video stays out of reach for ordinary amateur videographer.

Video frames are taken from camcorder's CCD chip about 25 (PAL) or 30 (NTSC) times per second. The exact video frame rate depends on the frequency of camcorder's internal oscillator. If the first camcorder's frame rate is f_1 and the second one is f_2 , then time disparity S will change over time as follows:

$$S = \frac{f_1 - f_2}{f_1} t + S_0, \quad (1)$$

where t denotes time and S_0 is initial disparity at time origin ($t=0$). For example, if the frame rate of the first camcorder were $f_1=25.000$ Hz and the frame rate of the second camcorder were $f_2=25.001$ Hz, the time disparity would be 2.4ms after 1 minute provided that they were perfectly synchronised at time origin ($S_0=0$).

Recently, some dedicated devices for synchronisation of still cameras and camcorders, like "LANC Shepherd" [4] or "ste-fra® LANC" [2], have appeared on the market. They are using the so-called LANC or CONTROL-L inputs on camcorders and still cameras to power-up the cameras at the same instant. Since both camcorders should be of the same type, they become relatively well synchronised at time origin (initial disparity S_0 (1) becomes relatively small). However, since internal oscillators in both devices are running at slightly different frequencies, the time disparity changes over time (1), and soon becomes unacceptable.

Drifting of time disparity can be eliminated by modifying oscillator's frequency of one camcorder. Namely, changing one frequency is enough to keep time disparity S as close as possible to 0. The question is how to modify the oscillator's frequency? Straightforward solution is to open the camcorder, find the oscillator's electronic circuit and apply control voltage to varicap diode connected to the oscillator's crystal. Varicap diode changes its own capacitance according to the applied voltage which results in modified oscillator's frequency. The additional requirement here is to have a controller which permanently keeps the time disparity at $S=0$. A practical example of proposed design can be found in [7], where time disparity was $S=\pm 50\text{ns}$. However, even though the achieved synchronisation was remarkable, the approach has one major drawback, i.e. it requires modification of existing camcorder's hardware. Firstly, this can only be done by a skilled electrical engineer (with appropriate service manual). Secondly, unauthorised modifications incur warranty loss and additional plug has to be placed on camcorder's body for controlling camcorder's frame rate.

The question remained is if there exists any other way of modifying camcorder's frame rate by using existing standard plugs without opening a camcorder? Yes, there is a way, but it applies only to some camcorders.

2. LANC

LANC¹ (Local Application Control Bus System) is a protocol developed by Sony which enables video devices to be controlled externally, usually from a connected LANC remote. Remote controllers, based on LANC protocol, are frequently used by video enthusiasts and professionals for controlling zoom, focus, record/pause commands, etc. The LANC protocol is similar to RS232 protocol with exception that video device is permanently sending so-called LANC frames which have to be filled with command codes. Shorter explanation of the LANC protocol, timing and codes can be found in [3]. Some specifics related to LANC communication with still cameras is given in [8].

LANC protocol has also been used for "hacking" some Sony camcorders in order to remove DV-input and video-input protection on some European models or to enable several hidden functionalities. However, it is less known that LANC protocol can also be used to view and modify some camcorder's internal settings like white balance settings, adjustments of brightness and contrast, etc. One of the most useful settings is oscillator adjustment. More precisely, LANC input can be used to *modify frequency of the internal oscillator on some models of Sony camcorders*². How can it be done?

By sending specific codes to camcorder's LANC input, basic camcorder functional settings can be altered by modifying data bytes stored on particular pages and addresses as shown in Figure 3. There are 16 pages (0-F) and each contains 256 addresses (00-FF) where 8-bit data is stored. For example, modifying data on Page F and Address 1C in camcorder Sony TRV-900E will change main oscillator's frequency and therefore camcorder's frame rate. Particular pages and addresses which affect camcorder's frame rate for several other Sony's camcorder models are given in Table 1.

The easiest way to alter camcorder functional settings through LANC input is to buy original Sony service remote and modify data at appropriate page/address. Cheaper way is to build simple electronic circuit and use parallel port of a PC and adequate software³ for emulating service remote controller [6].

¹ LANC is also known as Control-L.

² According to author's best knowledge, this feature is not available on still cameras produced by Sony.

³ Note that free versions of emulation software are mostly running on WIN95 and WIN98 systems.

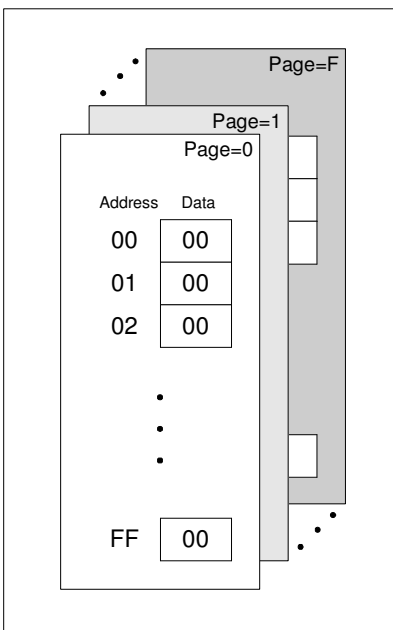


Fig. 3. Camcorder functional settings stored on pages and addresses.

Table 1 Pages and addresses of the data which affects frame rate for several Sony camcorder models

Camcorder model	Page (hex)	Address (hex)
DCR-TRV900(E), VX2100(E), DCR-PC1E, DCR-PC2E, DCR-PC3(E), DCR-PC10E, DCR-TRV9	F	1C
DCR-DVD91E, DCR-DVD101(E), DCR-DVD100(E), DCR-DVD200(E), DCR-DVD300, DCR-HC14E, DCR-HC15(E), DCR-HC16E, DCR-HC18E, DCR-HC20(E), DCR-HC30(E), DCR-HC85(E), DCR-PC106E, DCR-PC107E, DCR-PC108(E), DCR-PC330(E), DCR-PC350(E), DCR-TRV255E, DCR-TRV260, DCR-TRV260(E), DCR-TRV360, DCR-TRV361, DCR-TRV460(E), DCR-TRV461E	F	10
DCR-PC100E	F	12
DCR-TRV103, DCR-TRV410	F	40
DVD201(E), DVD301(E), HDR-HC1, DCR-HC40(E), DCR-HC65, DCR-HC1000(E), DCR-IP1(E), DCR-PC109(E)	frame rate cannot be adjusted	

Camcorder functional settings can be modified in two ways. The settings can be modified temporary by changing data in camcorder's volatile (RAM) or permanently by changing data in non-volatile (e.g. E²PROM) camcorder's memory. Temporary change of settings is relatively safe and the change is reset after switching off the camcorder. On the contrary, permanent change of data may stop the functioning of camcorder, since the checksum of non-volatile memory is calculated every time after turning on the camcorder. If the calculated checksum is different from the previously calculated checksum data, the camcorder stops functioning. Usually, frame-rate settings are not protected by the checksum.

An experiment has been conducted where camcorder's frame rate has been changed (modifying volatile or non-volatile data at page F and address 1C) for camcorder TRV900E. In accordance with modified data, the change of camcorder's frame rate has been detected.

3. SPECIFICATIONS

After promising result of the previous experiment it has been decided to develop a portable device which is able to control and maintain synchronisation of two camcorders.

The control device should comply with or have:

- two LANC ports for connecting two camcorders or still cameras,
- additional LANC port for connecting external LANC remote controller,
- HMI interface (keys and LCD display) with optional external keys,
- serial (RS232) connection with a PC (configuration and measurements),
- time offset measurement between two LANC frames with accuracy $\leq 1\mu\text{s}$,
- versatile power management (internal rechargeable batteries with long autonomy and different charging sources),
- closed-loop control of time disparity (if camcorder has appropriate setting for modifying oscillator frequency),
- commands for record/pause, tele/zoom, focus near/far, camcorder's menu operations, etc. and
- user-defined speed for tele/zoom operation and additional user-defined LANC commands.

The block scheme of device is given in Figure 4. Since the author had previous experience with Atmel microcontrollers, the microcontroller Atmel ATmega8 [1] has been chosen. It offers 16kB internal program memory, 1kB static RAM, 512Bytes of E²PROM, 3 counters, 10-bit ADC converter, USART (serial communication) and several interrupt sources. The microprocessor has been programmed by CodeVisionAVR Compiler [5], since it offers several pre-defined functions and templates (wizards) for ATmega8.

The device has been named "3D LANC Master".

4. 3D LANC MASTER

The electronic scheme of device is given in Fig 5. The core is microcontroller ATmega8, which is connected to LANC ports through open-collector inverters 74LS05 and to serial port via MAX232. The microcontroller is directly connected to 2x16 display LM016 and 4 keys (by using pull-up and pull-down resistors). The power is taken from rechargeable batteries and supplied by DC-to-DC converter MAX619. The electronic schemes, layouts and programmes are given in [8]. The circuit board is shown in Figures 6 and 7 and assembled prototype in Figure 8.

4.1 Inputs and outputs.

There are three LANC connectors in 3D LANC Master. Two are used for connecting two camcorders (or still cameras) and one for external LANC remote controller (if desired). The signals on LANC connector are the following: ground, power supply voltage (about 5.5V) and LANC signal. LANC signal (either LS, RS or MS) is connected to open-collector

inverters (74LS05⁴) in order to separate voltage levels (optical decouplers can be used as well, but current consumption should be taken into consideration).

Serial communication (RS232) with PC is enabled via 9-pin serial port (DB9) and MAX232.

In-circuit (ISP) programming of the microcontroller is enabled by connector K2.

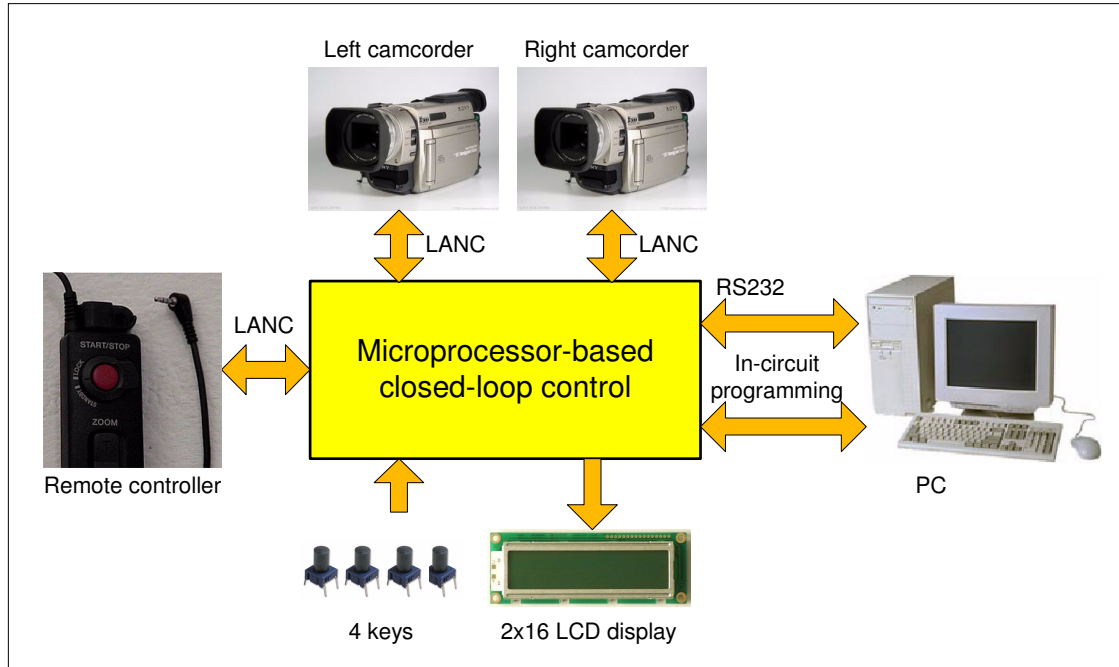


Fig. 4. Block scheme of 3D LANC Master.

4.2 Power supply.

3D LANC Master is powered by internal rechargeable batteries (3xAAA NiMH) in order to reduce power consumption of connected camcorders or still cameras (the latter are usually more sensitive to additional power consumption). The batteries can be re-charged either by connected camcorders/still cameras, by applying external power supply (4.5-6V DC voltage) on dedicated input or by charging the batteries in external battery charger. Charging is controlled by switch S1A (either 3D LANC Master is switched on or off). The charging current is controlled by a current source (transistors T₁ and T₂). The estimated battery capacity is shown on LCD display. It is estimated that 3D LANC Master functions for about 10 hours with one charging. The main switch is S2A. The voltage from the batteries is increased and stabilised to 5V by using DC-DC converter MAX619.

4.3 Human-Machine Interface.

On-board Human-Machine Interface (HMI) consists of keyboard and LCD display. The keyboard has 4 keys, 3 are function keys and one is SHIFT/MENU key. Display consists of two lines, each with 16 characters. Top line displays current commands associated to 3 buttons.

⁴ HCT05 version of the integral circuit is being currently tested.

Several other functions of 3D LANC Master can be achieved by using serial communication with PC [8].

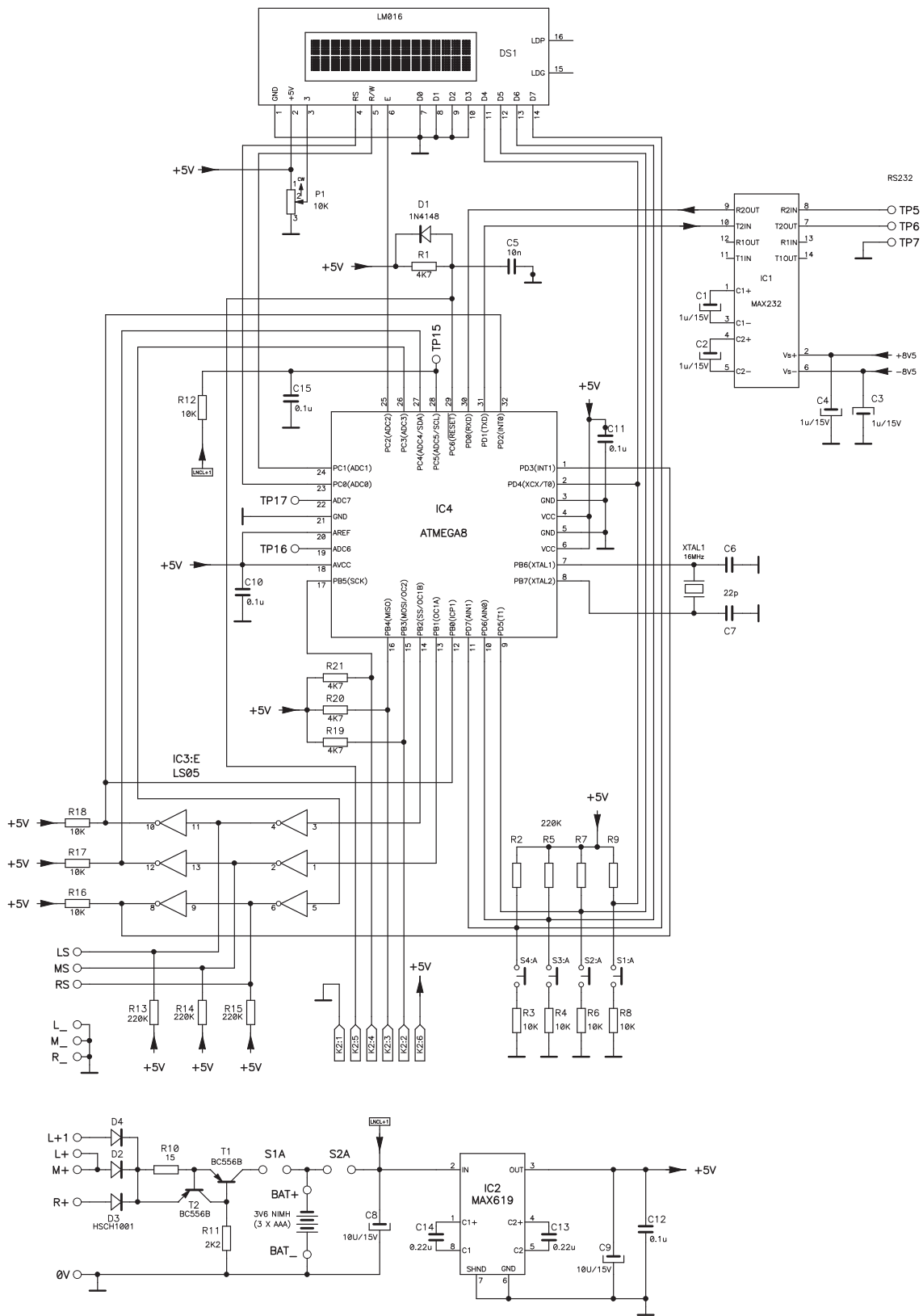


Fig. 5. Electronic circuit of "3D LANC Master".

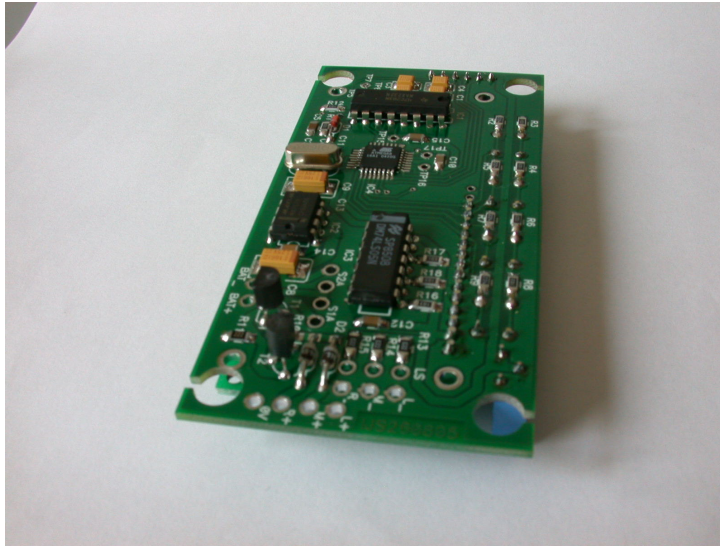


Fig. 6. Bottom side of the circuit board with elements.

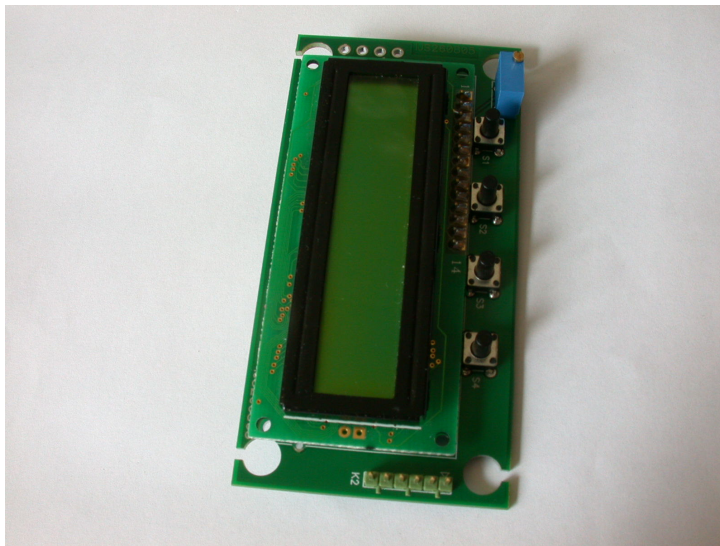


Fig. 7. Upper side of the circuit board with elements.

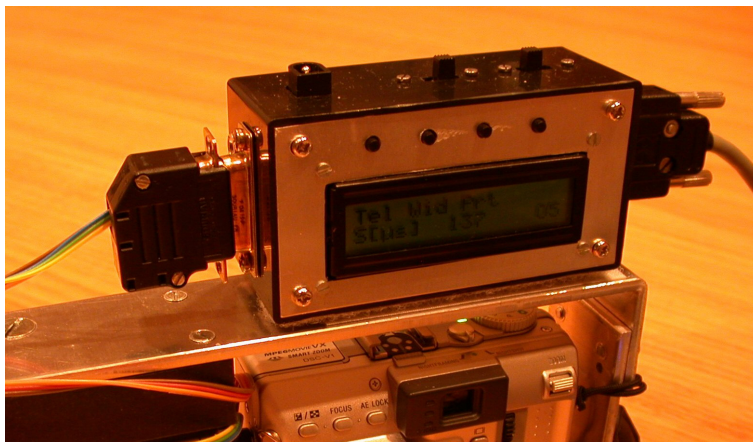


Fig. 8. Prototype of 3D LANC Master.

4.4 Functions.

The basic HMI (4 buttons with LCD display) offers the following functions:

- synchronous power-on/off, record/pause (pre-trigger/trigger for still cameras), tele/zoom, focus far/near, menu functions on camcorders (enter menu, up/down and submenu) and 2 user-defined LANC commands,
- permanent synchronisation of two camcorders (if the camcorder has settings for oscillator frequency),
- selection of display mode (time disparity in μs or recommended shutter speed for stereoscopy).

3D LANC Master can be configured via serial communication by using programme “3D LANC Communicator” on PC computer [8]. The following settings can be modified:

- page/address of the data responsible for frame-rate adjusting,
- duration and offset of power-on signal (separately for camcorder and still camera)
- duration of power-off signal during reset,
- speed of tele/wide commands for camcorders,
- proportional and integral gain of the PI controller responsible for keeping permanent synchronisation between two camcorders, and
- two additional LANC commands for camcorders.

3D LANC Communicator can also be used for monitoring time disparity (see Figure 9). The measured disparity can be saved as ASCII file or as Windows Meta-File (wmf) picture.

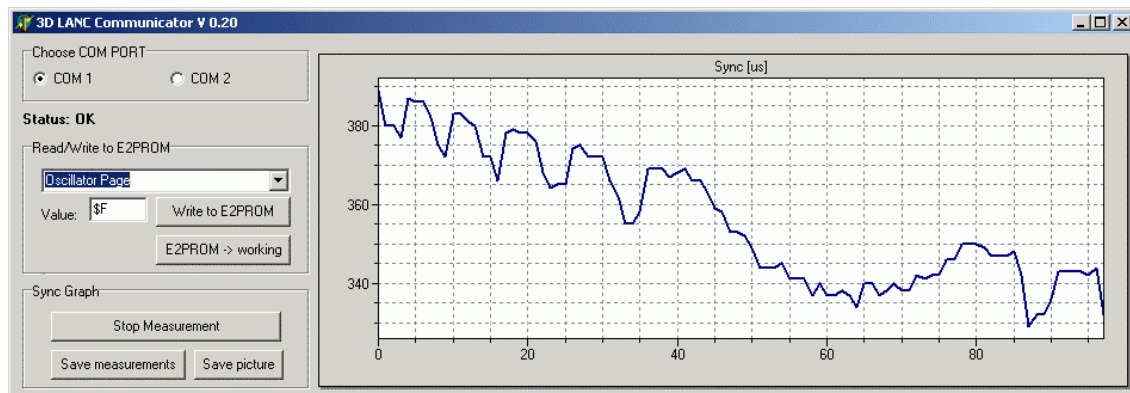


Figure 9. Adjusting parameters of 3D LANC Master and monitoring time disparity can be done by 3D LANC Communicator.

Camcorder’s internal settings (data in pages/addresses) can be adjusted by programme 3D LANC Doctor [8] (see Figure 10). The programme enables viewing and modifying the data in particular page/address (in volatile and non-volatile memory).

5. CLOSED-LOOP CONTROL ALGORITHM

In order to keep two camcorders synchronised, the closed-loop control has to be applied. A PI controller structure has been selected:

$$u(t) = K_p e(t) + \int_{t_0}^t K_i e(\tau) d\tau, \quad (2)$$

where u is controller output, e is measured time disparity in μs , K_p is proportional gain and K_i is integral gain of the PI controller. Signal u represents camcorder's data byte at particular page/address (depends on camcorder model – see Table 1). Integration inside expression (2) is performed only when calculated u is between 0 and 255, otherwise u is limited to either 0 or 255. The initial value of the integrator is the first measured value of data byte.

Proportional gain (K_p) and integral gain (K_i) can be adjusted with programme 3D LANC Communicator by modifying proportional factor (PF) and integral factor (IF):

$$K_p = \frac{1}{PF}$$

$$K_i = \frac{1.28}{IF} \quad (3)$$

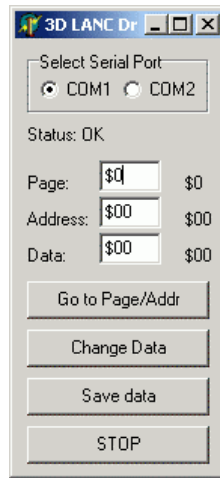


Figure 10. “3D LANC Doctor” can modify camcorder’s internal settings by changing data within camcorder

6. RESULTS

When 3D LANC Master was built, it was tested on two Sony DCR-TRV900E camcorders. First, reset impulse of length 100ms was sent to camcorders. After 20 seconds 3D LANC Master has been switched into the closed-loop configuration (PI controller became active). PI controller parameters were $K_p=0.25$ (PF=4) and $K_i=0.005$ (IF=256). The corresponding time disparity is shown in Figure 11 and histogram of the signal is shown in Figure 12. It can be seen that time disparity remained within $\pm 10\mu\text{s}$ after 200s and practically within $\pm 5\mu\text{s}$ after 1000s.

Another experiment has been conducted on two Sony DSC-V1 still cameras. The reset impulse of the same length (100ms) was sent to both cameras. Time disparity is shown in Figure 13. Since the closed-loop control of time disparity is not possible, the cameras cannot be kept in synchronisation.

The accuracy of measured time disparity with 3D LANC Master was verified by shooting computer CRT monitor with two camcorders. Camcorder shutter speeds were 1/10000s. The monitor refresh rate was set to 100Hz and resolution to 768 horizontal lines. Horizontal refresh frequency was 81.4kHz, so electron beam takes about

$$t_L = \frac{1}{f_V} = 12.3\mu s \quad (4)$$

to draw one horizontal line on the screen.

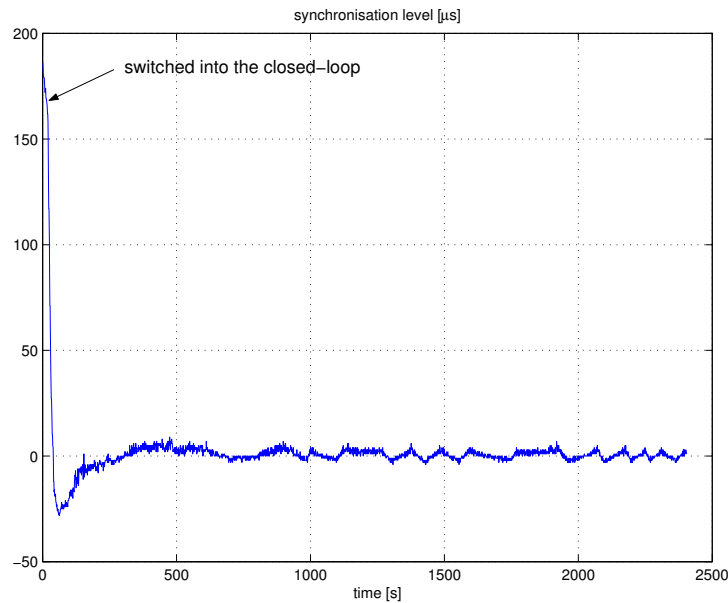


Figure 11. Time disparity of two camcorders

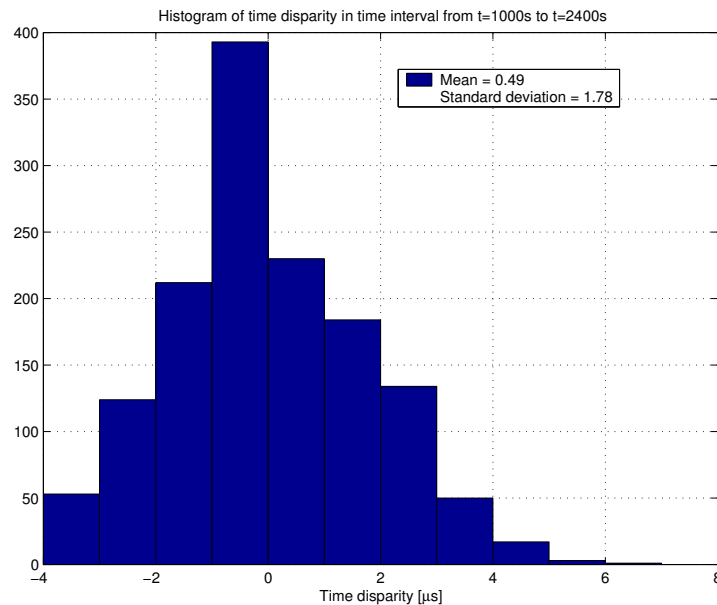


Figure 12. Histogram of time disparity of two camcorders in time interval $t=1000s$ to $t=2400s$.

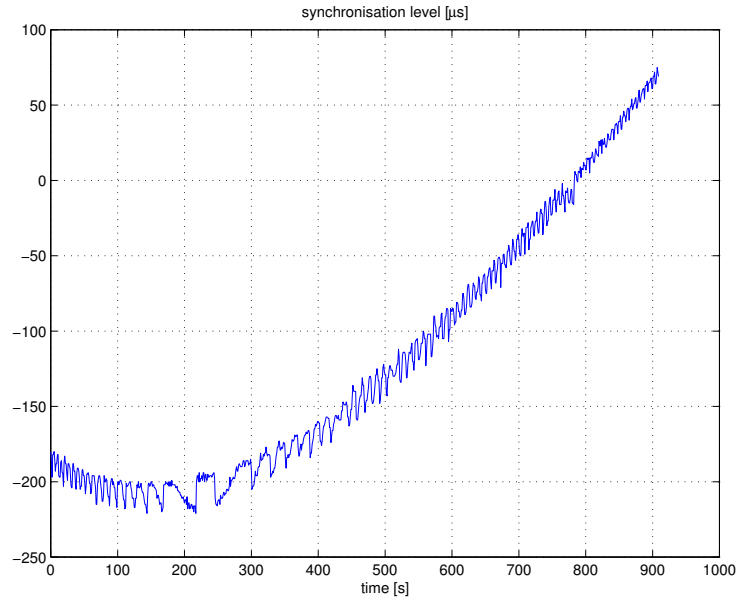


Figure 13. Time disparity of two still cameras

Figure 14 shows a part of one progressive frame from both camcorders when the shown time disparity (on LCD display) was $180\mu\text{s}$. It can be seen that the time difference between both pictures is 15 lines (see left edge of the picture). The actual time disparity is therefore:

$$t_D = 15 \cdot t_L = 184\mu\text{s}, \quad (5)$$

which corresponds to the measured time disparity.

Another measurement was taken when both camcorders were under the closed-loop control and the measured time disparity was $2\mu\text{s}$. From frames in Figure 15 it can be seen that the difference between both pictures is about 1 vertical line. According to (5), the actual time disparity is about $t_D=12\mu\text{s}$. It corresponds to the measured disparity within less than one horizontal line ($12\mu\text{s}$).

Figures 16 and 17 show the pictures taken by Sony DSC-V1 still cameras (measured disparity was between $50\mu\text{s}$ and $100\mu\text{s}$).

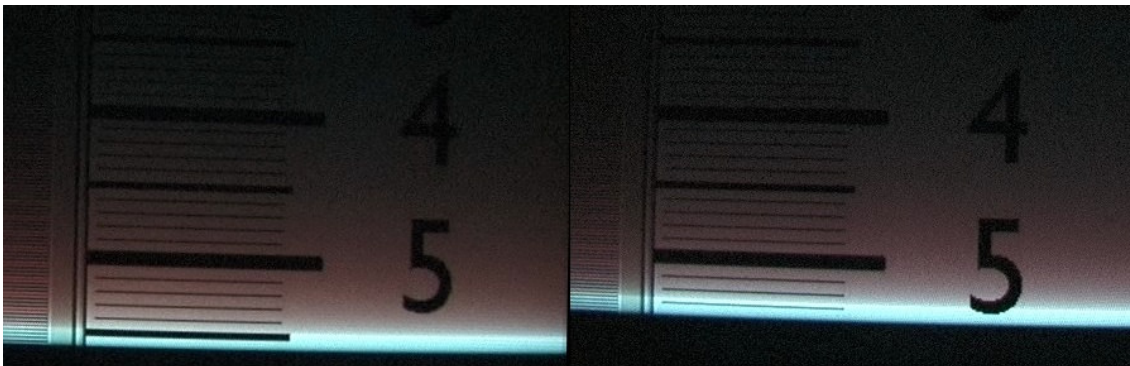


Figure 14. Video frames of two camcorders when the measured time disparity was $180\mu\text{s}$.



Figure 15. Video frames of two camcorders when the measured time disparity was $2\mu\text{s}$.



Figure 16. Left-Right-Left picture taken by two Sony DSC-V1 still cameras.



Figure 17. Left-Right-Left picture taken by two Sony DSC-V1 still cameras.

7. CONCLUSIONS

A device named “3D LANC Master” has been made for synchronisation of two camcorders (or still cameras). The device requires LANC signal on both camcorders in order to simultaneously power-on both camcorders (still cameras). It can permanently keep some types of camcorders, produced by Sony, in synchronisation. 3D LANC Master simultaneously sends LANC commands to camcorders or still cameras according to pressed buttons, received commands from standard LANC commander, or commands received via serial (RS232) communication.

The device is powered by internal recharging batteries in order to reduce power consumption of connected camcorders or still cameras (the latter are more sensitive to additional power consumption). 3D LANC Master works for about 10 hours with fully charged batteries, which can be recharged in different ways.

Some internal parameters of 3D LANC Master can be configured by using programme 3D LANC Communicator. The programme is written for PC computers and offers visual

inspection of time disparity as well. Some camcorder's parameters can be modified (with extreme caution!) by using programme "3D LANC Doctor".

It was shown that 3D LANC Master worked on a pair of Sony DCR-TRV900E camcorders, where permanent time disparity within $\pm 10\mu\text{s}$ has been achieved. Unfortunately, permanent synchronisation can be achieved only on some camcorders (according to Table 1)

REFERENCES

- [1] Atmel. Atmel Corporation. <http://www.atmel.com>
- [2] Bloss, W. ste-fra® LANC. http://www.digi-dat.de/produkte/index_eng.html.
- [3] Boehmel M. How SONY LANC™ protocol works. <http://www.boehmel.de/lanc.htm>.
- [4] Crockett, R. LANC Shepherd. <http://www.ledametrix.com/index.html>.
- [5] HP InfoTech. <http://www.hpinfotech.com>.
- [6] Kovacevic M. Enabling DV-IN on D8 & DV. <http://lea.hamradio.si/~s51kq/DV-IN.HTM>.
- [7] Vrančić, D. (2004). Synchronizing two camcorders.
<http://www-e2.ijs.si/damir.vrancic/personal/trv900/Sync/>.
- [8] Vrančić, D. (2005). 3D LANC Master.
<http://www-e2.ijs.si/3DLANCMaster/>.