CCD linear image sensor ILX 511 arrangement for a technical spectrometer

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The practical use of the CCD linear image sensor ILX511 for scanning of light in some optical applications (spectroscopy) is presented. Communication of the equipment (CCD linear image sensor) with a computer is realized with the help of a parallel interface of a personal computer without an additive interface card. The use of the line detector is presented on the example of detecting the optical spectrum of a mercury lamp.

1. Introduction

The measurement of luminosity is still an actual problem. A recent trend is to take measurements in co-operation with a computing system. The wiring diagram of a measuring circuit is based on the use of a suitable detector for which the signal of the circuit is proportional to luminous intensity. This signal is further digitized and then stored with the help of the interface in the memory for the subsequent processing. The whole equipment may be engineered in the form of a suitable board (for example, the firm Eureka Messtechnik HmbH in Köln, Germany, offers line scan camera circuit boards for PC link type LSO-2048SH1-8EPP, price 395 Euro [1]). In our case we created the interface of CCD detector ILX511, Sony (or similar), connected to a personal computer (IBM PC) with the help of an enhanced parallel EPP-IEEE-1284 port, so that no additional interface cards are needed. The control is made by direct port accesses and without any special drives or libraries. The system interrupt of the operating system of the computer type IBM PC was used for obtaining the constant sensing time [2]. With the help of programming at a low level (assembler) we reached the minimum time up data transmission between the sensor and computer. Scanning of Hg lamp spectrum was conducted for verification purposes.

2. Realization of the interface ILX511

Our aim was to propose an equipment which would meet the following requimerents: the computer interface function in point of view of design simplicity, high speed, easy implementation into a host computer and low purchase price. Most sensors of new generation, like *e.g.* ILX511 from the Sony family, may be controlled only by two signals [3]. The strobe signal FROG is used for line sampling and FCLK phase clock signal is used to charge shifting. Then, an idea arose to generate FROG and FCLK for driving CCD scanners and at the same time to use them to control data transmission. EPP protocol is well adapted to meet this target, it makes possible high-speed handshaking and is easy of access in today's PC architecture. All other processes are thus being urgently synchronized with those signals [2], [3].

Schmitt's flip-flop circuit type MM74HC14 was used to construct both the time interrupt generator and assure the reservation logic of whole design (Fig. 1).
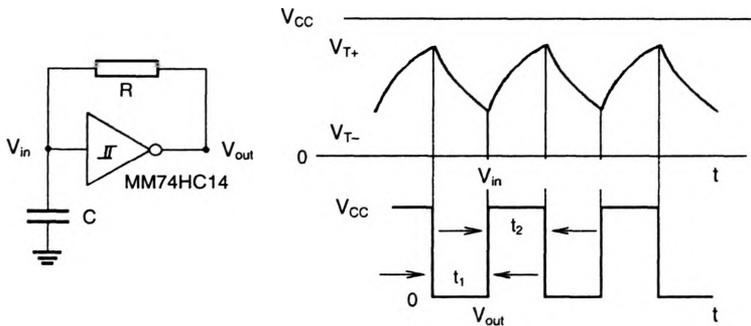

Fig. 1. Low power oscillator circuit with MM74HC14 (V_{in} and V_{out} as function of time t).

The time path signal of the designed low power oscillator can be described by the relations

$$t_1 \approx RC \ln \frac{V_{T+}}{V_{T-}}, \qquad t_2 \approx RC \ln \frac{V_{CC} - V_{T-}}{V_{CC} - V_{T+}} \tag{1}$$

where $t_1 + t_2 = T$ means the time period of the low power oscillator, R and C are resistance and capacitance of the oscillator and V_{T+}, V_{T-}, V_{IN}, V_{OUT} (in Fig. 1) describe the maximum and minimum of the voltage course in the analog and digital form, respectively. At knowledge V_{CC} (supply voltage) we can extract formula for frequency

$$f \approx \frac{1}{RC \ln \dfrac{V_{T+}(V_{CC} - V_{T-})}{V_{T-}(V_{CC} - V_{T+})}}. \tag{2}$$
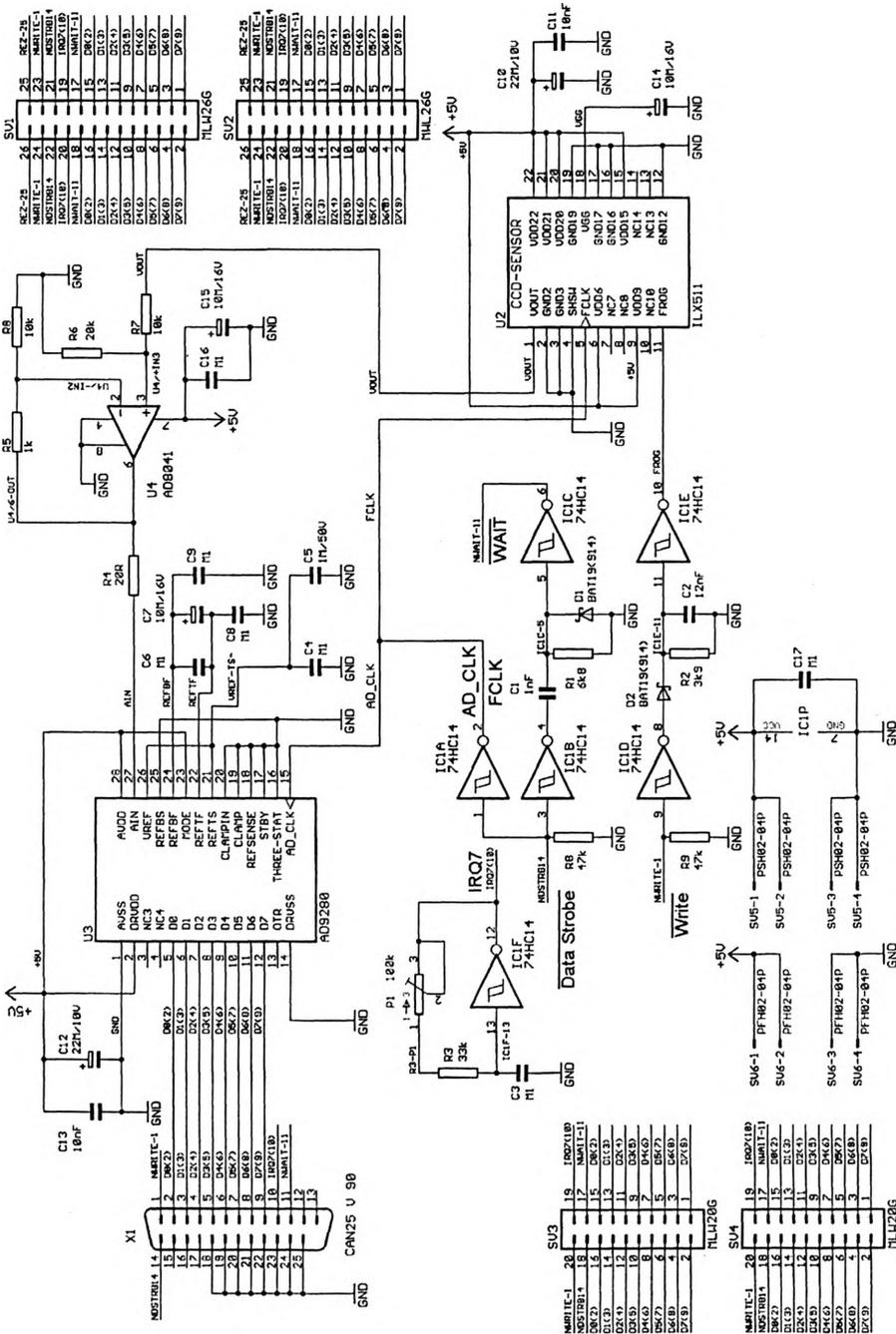
Fig. 2. Design of ILX511 interface PC with a converter of AD9280 type.

The equations assume $t_1 + t_2 \gg t_{pd0} + t_{pd1}$ where typical propagation delay $t_{pd} \approx 13$ ns. For practical application we can write the frequency of Schmitt trigger circuit by the expression

$$f = \frac{1}{T} = \frac{1}{0.67RC}. \tag{3}$$

The circuit in Fig. 2 consists of linear CCD scanners (ILX511, Sony), fast A/D converter (AD9280, Analog Devices), timing generator and pertinent logic. This one is realized with the help of a sextuplet Schmitt's inverter (74HC14s). The power supply of the whole circuit is provided by the independent source $5V_{DC}$.

The control signal $\overline{\text{Write}}$ generated in the "Data Write Cycle" mode of the EPP, produces the FROG signal by using the signal delay $\overline{\text{Write}}$ (Fig. 2). The signal $\overline{\text{Data Strobe}}$ generates AD_CLK and FCLK signals which serve as pixel clocks for the shift operation and the A/D conversion (AD9280) simultaneously. During the $\overline{\text{Data Strobe}}$ signal the analog CCD signal is sampled by using the internal sample-and-hold circuit of the ILX511 (due to the SHSW pin on GND) with an output on V_{OUT} pin and digitized with the help of the AD9280 circuit. Digital data from the A/D output on D_0–D_7 are stored into PC memory during the signal $\overline{\text{Wait}}$, which is generated by circuit elements 1C1B, 1C1C, C1, R1, and D1. The sampling pixel period is directly proportional to the $\overline{\text{Data Strobe}}$ period and can be adjusted by modifying the R1/C1 time constant. In the contemporary implementation of the EPP protocol the sampling pixel period is limited to a minimum 0.5 μs. From a software point of view, the described operations can be controlled with three lines of code only:

```
outportb (adr_port + 4, 255); /*generate FROG*/
for (i = 0; i <= num_pixel; i++) /*acquire pixels*/
*(row+i) = inportb( adr_port+4 ); /*storage data*/
```

The usage of question methods is not possible because the $\overline{\text{Write}}$ period of the signal depends on the software flow. The hardware interrupt IRQ7 is easily accessed from the parallel port and can be used to solve this problem. Specially, the oscillator built with the aid of 1C1F produces a line read strobe signal.

3. Realization of the line camera

The designed circuit has been repaint into a form of the printed circuit by means of the program type Eagle 4.1, corroded suitable board of proportions 6 cm and 5 cm and staffed by relevant components and connectors, see Fig. 3a, b.

Computerized solving of communication has been realized according to the above project. Power supply $5V_{DC}$ voltage is suggested either of independent source or it is also possible to use the employed computer. At starting implementation of the EPP protocol the strobe period of the pixel is set on minimum 0.5 μs (R1C1, Fig. 2), so that the time on 2088 samples per row is 2088×0.5 μs = 0.001044 s per row.

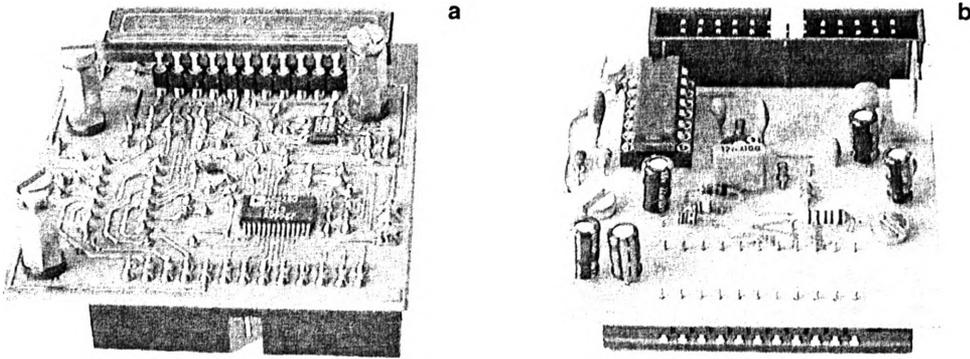In our case the time of the interrupt for one row setting has double value, in accordance with the application formula

Fig. 3. Front look of the make-up scan camera (**a**), and backside look of the scan camera with connectors (**b**).

$$0.67R_3C_3 = 0.68 \times 33 \times 10^3 \times 100 \times 10^{-9} = 0.0022 \text{ s,} \tag{4}$$

so that sampling rate (3) of the lines has the frequency

$$f = \frac{1}{T} = \frac{1}{0.67R_3C_3} = \frac{1}{0.0022} = 454.54 \text{ rows per s.} \tag{5}$$

4. Use of CCD linear sensor in spectroscopy

An example of the use of the linear CCD sensor is its application in spectroscopy. If we put a transparent holographic grating in a convergent beam of light (Fig. 4) we can see on the scale (in a focus plane F of the convergent beam) spectra of the light (rainbows) in a visible range from violet and blue across green and yellow to orange and red [4].
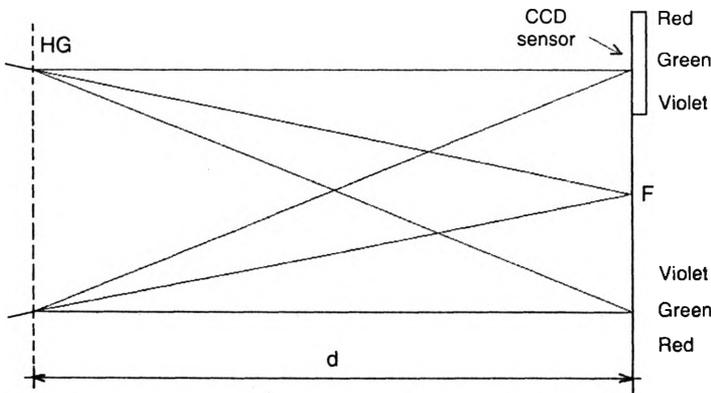

Fig. 4. Diffraction of a convergent beam of light on a holographic grating (HG), d – distance, F – focus plane of the convergent beam.
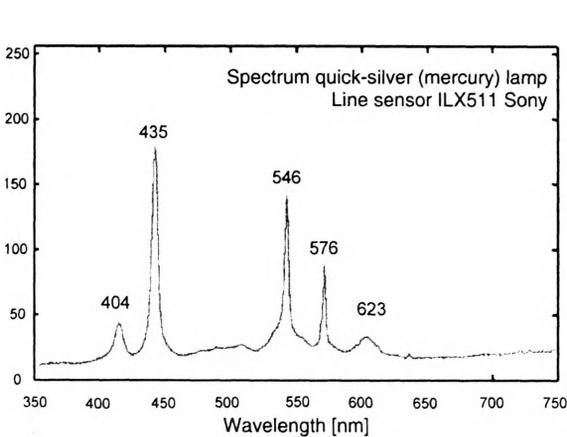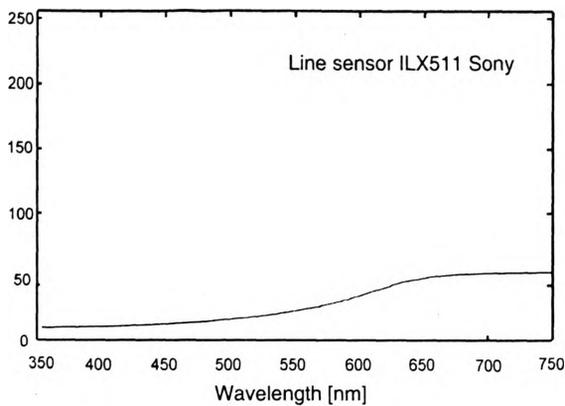
Fig. 5. Spectrum of a metal filament lamp (**a**), and spectrum quicksilver lamp (**b**).

From the record of spectrum of a metal filament lamp (Fig. 5a) it is clear that the linear sensor ILX511 is very sensitive, especially in the area of reds colors. That is why for the recorded linearity of the whole spectrum it is necessary to smooth the sensitivity of the sensor by suitable software. Figure 5b illustrates the computerized corrected spectrum of a quicksilver (mercury) lamp (along Fig. 4).

5. Conclusions

The designed interface of the CCD detector ILX511 (Sony) can be connected with a personal computer (IBM PC) with the help of the enhanced parallel port EPP-IEEE-1284, so that no additional interface cards and special drives or libraries are needed. It enables communication of the detector and computer in very short time ($t > 0.001044$ second per row). For its simplicity, high frequency and low price it is suitable for numerous technical applications (for example, technical spectrometer).

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