INTELLIGENT PROGRAMMABLE INK STAMP WITH ADAPTIVE PRINTING SPEED

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Abstract: This paper is dealing with a concept and a physical prototype of an intelligent, electronically programmable stamp, based on an inkjet printing technology. The stamp basically represents a small embedded inkjet printer. The stamp can print a simple custom text and is meant to replace regular office stamps. The benefit of the proposed stamp may include cost reduction and eliminate a need for multiple stamps. The theoretical concept is followed by the prototype, which is an essential part of this work.

Keywords: Embedded system, stamp, print, cartridge, sensor.

1 INTRODUCTION

An ordinary ink stamp obviously represents a common item in virtually every office. Typically each situation or administrative act requires a different type of a such stamp, which may be quite cumbersome in terms of storage. Moreover, any substantial change in a stamp layout means that a completely new one has to be designed and manufactured. Even traditional widespread adjustable time stamps may introduce significant inconveniences if a user forgets to setup a date in an appropriate way. A possible answer and a feasible solution to these issues could be offered throughout a so called intelligent programmable stamp (abbreviated as IPS from now on). IPS can be recognized as a dedicated piece of equipment adopting the concepts of embedded systems where its single-purpose nature is strongly oriented on a possible mitigation of inherent drawbacks connected with a traditional office stamp.

The basic hardware arrangement of the intelligent programmable stamp is based on easily available components including a microcontroller and an inkjet printing head as core elements. The built-in intelligence characteristics, flexibility and a rich feature set of the microcontroller enables a relatively large volume of various text patterns and corresponding fonts to be uploaded into an internal memory of the IPS. In fact, utilization of a real-time module inside the microcontroller provides a smooth way towards an automatic update of time data to be printed within a target document.

Such a variant of an intelligent and configurable stamp may evidently come handy in a wide range of situations – printing of signatures, name initials, unique production of serial numbers on various devices or batch numbers on parcels, staple food expiration marking, book owner initials within a designated area of individual pages, barcodes and many others.

An attention throughout this work is focused especially on a design of an uncomplicated hardware and software solution for an adaptive printing rate with a dependence on movement speed information provided by an optical position sensor. Then, a physically manufactured device qualified for a hand-operated inkjet printing constitutes the overall achievement. This contribution is divided into several sections. First of all, two theoretically oriented sections provide a necessary introduction to principles of an inkjet printing technology and means of optical movement detection and sensing. Section 4 covers essential aspects of a device architecture. Furthermore, details of cooperation between the movement sensor and the printing head are outlined in section 5.

2 PRINCIPLES OF INKJET PRINTING TECHNOLOGY

The general principle of printing with this technology is based on the creation of minute drops of an ink, which may typically comprise the volume of 1pl ($picoliter = 10^{-12}\ l$). These ink drops are expelled from corresponding nozzles at a high speed of 50-100 kilometers per hour. Exact schemes of their production may vary a lot with respect to a given underlying technology. The most prevalent ones include a continual system, a piezoelectric system and a thermal system. The first two methods are closely surveyed in [2].

2.1 THERMAL SYSTEM

Thermal or heat-based systems for ink drops creation are considered to be the most frequently used out of the available ones. The core of this technology is concentrated around a transfer of a right amount of heat into the nozzles which are used for a delivery of an ink onto a printing media. Similarly to the piezoelectric system, small ink depository cells are used in case of a heat-based technology. However, unlike with the piezoelectric system these depository cells aren't subjected to any shape deformations or temporary structural changes. The primary task of a heating element placed within the immediate vicinity of a depository cell is focused on liquid media, i.e. an ink, warming, see Fig. 2 on the left for more details. An operation of the thermal system is internally divided into three consequential phases. The depository cell filled with an ink is heated first. This step leads to a formation of a small bubble which, as a result, is continuously increasing pressure inside the cell. During the second phase the growing pressure exceeds a certain threshold and the content of the depository cell is partly expelled onto a surface being printed on. The depository cell with a small amount of a warm ink is subjected to a rather fast cooling down process which purposely leads to an emergence of vacuum. During the last phase a ink is drawn back into the cell again from the main storage tank within the cartridge and a nozzle with the depository cell attached to it is ready for the next printing cycle [3].

3 PRINCIPLES OF OPTICAL SENSING

In order to avoid an undesirable warping of a text pattern being printed with respect to an actual movement speed, it's more than vital to efficiently track the dynamics of IPS position change. Several different types of convenient sensors, including optical encoders, CCD camera elements or accelerometers, could be selected for that purpose. Nevertheless, the most easily accessible variant with desired properties is probably the camera sensors used in computer mice. The most notable factors are closely tied with a small size and a relative simplicity of its exploitation for the intended purpose. Such a type of a sensor mostly contains an embedded camera with resolution around 16 x 16 pixels alongside a picture process logic and a communication interface with the surrounding environment.

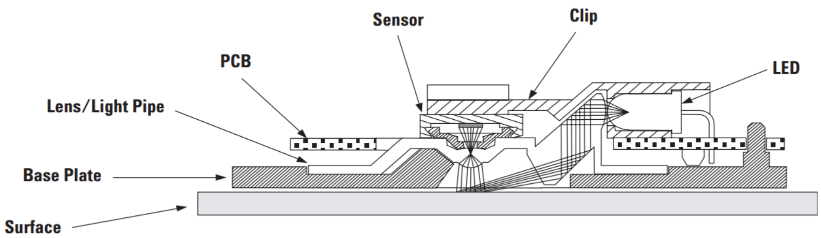

Figure 1: Principles of optical sensors [5].

Principles of the area sensing and illustration of the general operation is given on Fig. 1. First of all, a LED diode emits some amount of light into a prism or a mirror. A Light beam is subsequently refracted under a specific angle and forwarded onto a scanned surface. Illuminated part of the surface underneath is processed through a CCD sensing element. It can produce a picture composed of 16 x 16 pixels, which is stored in an internal memory at the end of the sensing process. The following step brings another picture which is automatically compared by the algorithm implemented directly within the CCD chip with the previous one. In other words, the mutual differences between these two frames are evaluated and it provides a basis for an estimation of a direction and a movement speed. The obtained difference of picture shift is then written into a register, where it's available through a communication interface like USART, SPI or even directly via USB.

4 CIRCUIT LEVEL SOLUTION

The actual system was designed with an office or similar deployment environment in mind. Such a notion means that its current version doesn't qualify for an operation under the outdoor conditions. A physical arrangement of the device resembles a small compact box or a locker which contains a whole range of necessary electronic blocks and mechanical elements, thus, integrating the complete system functionality. So, the user doesn't have to be aware of the fact that a basically small computing system dwells inside the main case. An interaction with a user and an overall device control is carried out throughout a tiny keyboard in a combination with an LCD display. A text pattern to be printed can be entered by means of using the available keyboard or, as an alternative way, the USB port allows the text to be uploaded. Figure 2 on right shows a block schematics which depicts the main aspects of a device architecture and principle of operation.

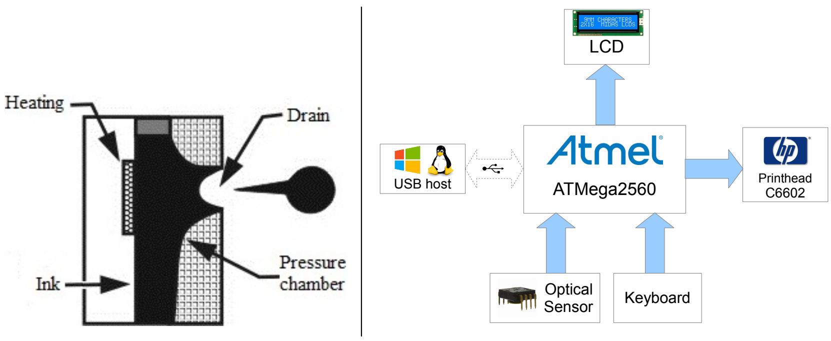

Figure 2: The principle of the thermal printing (left) [2], block schematic (right).

4.1 PRINTING HEAD

IPS is using a printing head C6602A, which contains 12 nozzles adopting the thermal principle of operation, as explained in chapter 2.1. Number of heating elements is connected as a resistor network with a common power supply rail. Each nozzle of a printing head is permanently connected to a supply voltage of 20 - 24 V. Negative terminals of printing nozzles are taken out to the interface connector. A Grounding of a given negative terminal will close the electrical circuit which will increase temperature of a heating element adjacent to a particular nozzle. NMOS transistors, where the gates are controlled by I/O pins of a microcontroller ATMEGA 2560, behave as the switches responsible for the grounding the negative terminals. All these transistors are closed, or put into a non-conductive mode, in a default state. Therefore it prevents the nozzles to be effectively grounded, which results in an opened electrical circuit. A Positive supply voltage attached to an arbitrary gate will open the transistor, a conductive path is created across it, and close the electrical circuit for a given nozzle, where the voltage of 20 - 24 V can be finally observed.

Proper timing of these switching periods is more than crucial for a reliable and long-term device operation. If the voltage is applied to a nozzle for a too long period of time, it will cause the nozzle to cease from normal operation forever. The point is that the nozzle isn't allowed to cool down properly under such an excessive strain, which will ultimately result in its permanent damage. From this point of view it's necessary to match several timing constraints to prevent such an extreme situation [4]:

- Maximum allowed time of voltage application to the nozzle: $3-6$ *us*
- Minimum time between repeated voltage application to the nozzle: $\geq 0,5$ *us*
- Minimum necessary time for nozzle cooling: ≥ 800 *us*

4.2 OPTICAL CAMERA SENSOR

An integrated circuit with an optical sensing element, i.e. CCD camera, is equipped with a serial communication interface which consists of two signalling wires. A communication is always initiated by a master entity and the optical sensor behaves only as a slave device. The operation of the optical sensor is carried out throughout several statuses and control registers. A master entity has an access to these registers so it can fetch a content of status registers or adjust settings in control registers, on the other hand. The most important is the register which makes available the number of pixels (with respect to a sensor resolution of 400 cpi) travelled since the last access to the register. It suggests that the readout operation of a current value is destructive and it cannot be applied on a given result more than once. Such a type of register is available for each movement axis.

5 COOPERATION OF OPTICAL SENSOR AND PRINTING HEAD

A deformation of a printed text can be avoided to a large extent by a smooth cooperation between the two fundamental parts of the intelligent stamp discussed above – a printing head and an optical position sensor. The previous sections have covered these components in detail, so the attention will be given to the implementation of a system-level firmware in order to combine their functional properties into a desired printing output.

The initial idea behind the combination of an optical sensor and a printing head is the following: if the stamp movement is slow, decrease the printing speed; or, if the stamp movement is fast, try to increase the printing speed. Rich set of experiments have confirmed that the precision of an optical sensor is very sensitive to an actual type of a surface the stamp is moving on. That clarifies the reason why it was necessary to implement a type of a filter which is computing an average value based on last 4 measurements. The suggested printing algorithm, utilizing the data from an optical sensor, can be outlined in the following way:

1. Wait for a button press indicating the start of a printing procedure, set $n = 0$.
2. Detect the movement in X-axis, $tracklen_n$.
3. Compute a delay between printing of individual vertical stripes (inverse proportion – the longer path means lower delay).

$$tracklen = \frac{tracklen_n + tracklen_{n-1} + tracklen_{n-2} + tracklen_{n-3}}{4} \; [cpi] \tag{1}$$

$$delay = \frac{1}{tracklen} \; [\mu s] \tag{2}$$

4. Print one vertical strip.
5. Wait for $delay$ $[\mu s]$.
6. Fetch new data for printing of a vertical stripe.

7. If printing data available, $n = n + 1$ and goto 2. or finish.

The algorithm proposed above brings a possibility to adapt the printing rate with respect to the actual stamp movement speed. As it turns out quite satisfactory result may be obtained with the algorithm. On the other hand, the constraining speed limit of a printing head movement with relationship to the prescribed timing parameters for nozzle cooling was discovered. The speed limit is about $0,325ms^{-1}$. In addition, excessively slow movement brings another sort of problems related to the properties of an optical sensor or a change of a position detection. The optical sensor was initially designer for computer mice where exists an effort to keep a mouse cursor within the same line of an image raster. Subsequently, detection of minute movement within a given axis cannot be identified reliably, because the sensor logic simply eliminates them [1]. The slow movement was measured experimentally and found that the slowest possible motion is about $0,01ms^{-1}$.

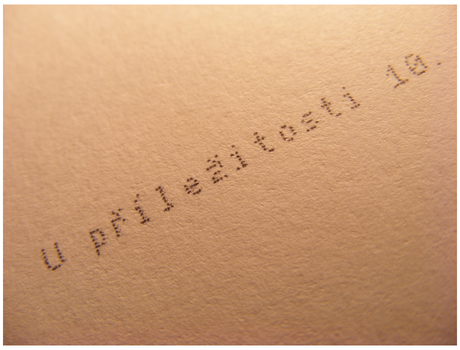


Figure 3: Printed text (left), realised device (right).

6 CONCLUSIONS

The main outcome of this work is represented by a functional and tested prototype of an intelligent programmable stamp, as suggested in the introductory section. The exact physical appearance of the prototype can be seen on Figure 3. A mutual cooperation between a printing head and an optical sensor works quite satisfactory, but boundary conditions for a reliable operation and also unwanted properties of an optical sensor were identified. The conditions for the stamp operation are exposed to the fact that it's virtually impossible to print at infinite speed or, the other way around, in a very slow manner.

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