A Microcomputer-Based Ink Control System Using Infrared Detect Technology

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Abstract: An automatic ink control system was developed with infrared measuring technique and microcomputer controlled stepping motor to improve the printing quality through the precise adjustment of the quantity of ink on the ink roller. This study included: a). performance analysis of current ink control system on offset press, b). design and implementation of an infrared measuring device, c). testing and adjustment of this infrared measuring device, d). software programming, e). comparing and analyzing each result of Yellow, Magenta, Cyan and Black processed inks on "IR tester" and f). simulating the ink control process to improve the performance of microcomputer-based ink control system. An infrared LED was used as the light source and a photo-diode was used to pick up the signal reflected from the surface of the roller. It was then converted into digital signal through OPA and A/D converter for computer processing. The experiment results showed that the predefined color could be precisely controlled with this automatic ink control system.

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Introduction

The stability of ink supply is the key factor for high quality mass printing. Several ink setting systems have been developed in the past decades to improve the quality of ink control system, such as Heidelberg CPC1, CPC2, CPC3, Roland RCI, Miller C3, Mitsubishi S-11, Akiyama ACC, and Komori PQC. All these systems use color guide to check the ink density with naked eyes and control the opening of ink cell with microcomputer in a remote control style (Huang, 1989). The advantage of this remote control system is in the time saving of running between print-out device and ink density controller. But most skilled worker can't guarantee the stability of ink density in this manual guide-based ink control system. Especially for mass production, the difference of ink coverage between the first page and the last page may be vast due to the error of manual control. Therefore, an automatic control system for ink density is needed to improve the stability of ink coverage on printing production, especially for the fast printing machine (Boumaiza, 1997).

One method used by some printing companies to improve the ink stability is through the analysis of image grasped by plate scanner to preset the ink density. But the resolution of scanner will cause some error during worker's observation. However, most traditional printing companies still used the sampling and observing method to adjust the ink quantity (Chu, 1997). They may sample three sheets in every two hundred sheets and select one of them as a reference to adjust the ink level. But the quality of this method depends on the experience of printing worker. It is not available for a novice worker.

An economical and effective method for improving the stability of ink density may be the application of infrared technique. It is found that the radiant flux in mW versus the dc forward current for a typical GaAs infrared LED appears linear relationship (Boylestad, 1982). This linear characteristic makes it useful for signal detection. And the wavelength of far infrared between 15um~200um has been used for remote control with high reliability in television, camera, office machine, color coder, and fire alarm.

In printing case, the luminous efficiency of reflected light to incident light of infrared LED can be used for checking the thickness of ink film as the following:

$$V = \int S(\lambda) R(\lambda) D(\lambda) d\lambda$$

where S is the spectral incident power of the LED source, R is the spectral reflectance factor of the ink, D is the spectral responsivity of the LED detector, V is the output voltage of the LED detector. Once the relation between V and R is established, the ink film thickness can be predicted by the measured voltage V on the LED detector. And the thickness range of ink film is about 0.7 μm to 1.1 μm in offset printing. Furthermore, the relationship between ink film thickness and ink density can be described in the Figure 1 (Tsai, 1991). It is shown that the relationship between these two variables within the above range is linear. Thus the efficiency of reflected light of infrared LED can be used for the adjustment of ink density.

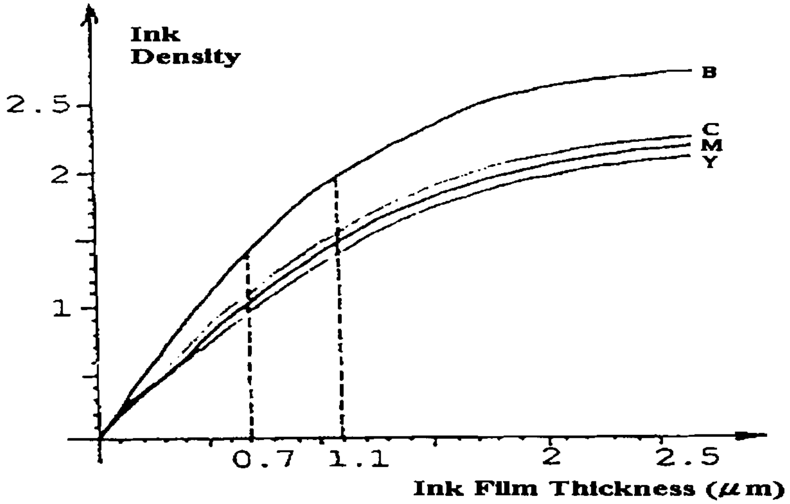

Figure 1. The Relationship Between Ink Film Thickness and Ink Density

System Development

Based on the above concept, a real time ink density automatic control system can be developed through the availability of infrared LED, reflected infrared sensor, and microcomputer. The development process is outlined as Figure 2. And the implementation principle is as the followings:

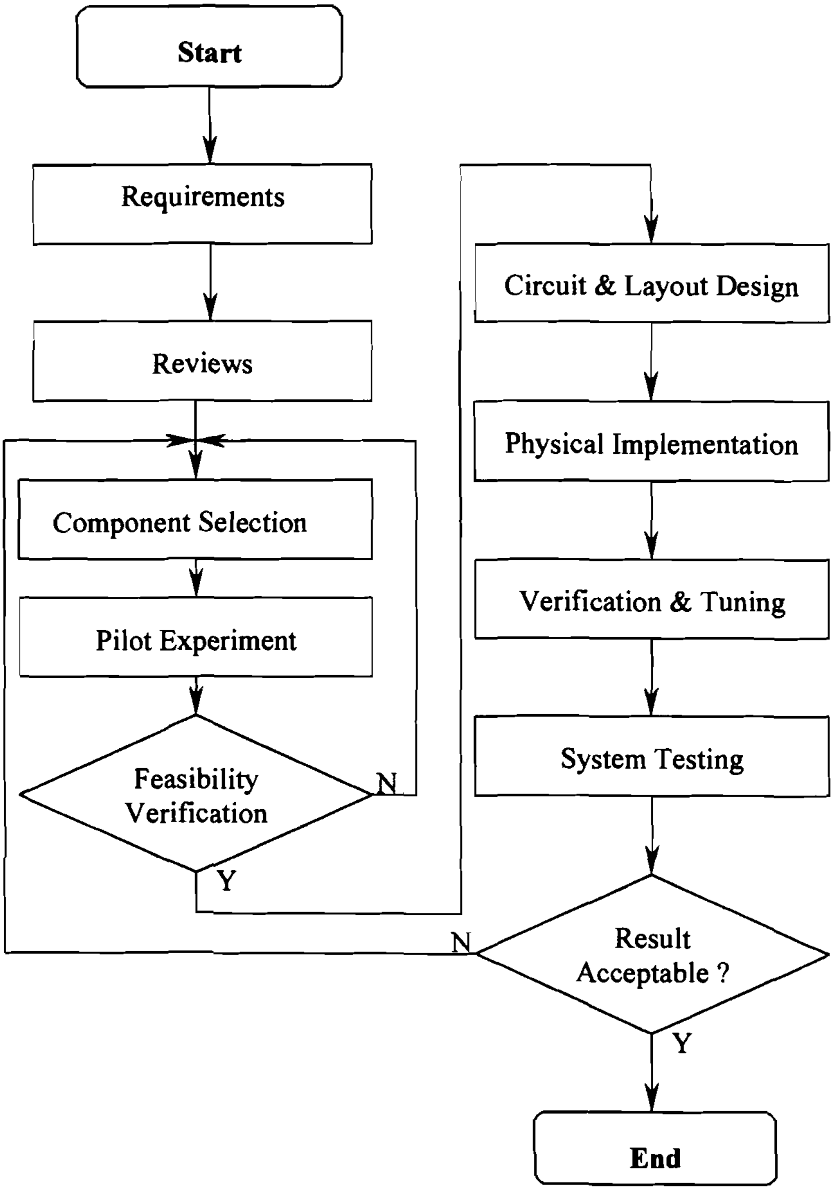

Figure 2. System Design and Implementation Workflow

1. The ink control monitoring process is implemented in the real-time fashion during the printing process.
2. The standard ink setup is determined by the operator during the make ready stage to set the target reference condition.
3. The range of the upper-limit and the lower-limit for the acceptable ink amount is adjustable. Various alarm strategies can be selected.
4. The reliability of signal exchange is ensured by the handshaking method.
5. The consistency of the signal is improved by multiple sampling and value-averaging method.

System Configurations

The system consists of several components as the followings:

1. Data Acquisition Unit
2. Analog to Digital Conversion Unit
3. Process Unit
4. Ink Control Unit

The data acquisition unit houses the infrared light source and infrared sensor to probe the ink film thickness on the roller by infrared signal. The A/D conversion unit receives the analog optoelectronic values of the reflected infrared signal and then converts it to digital signal ready to feed the process unit. The process unit compares the real time input signal with the stored reference data and determines the amount of compensation needed for the ink control unit to adjust on the printing ink. Figure 3 shows the system configurations.

Data Acquisition Unit

The main components in the data acquisition unit are infrared light source, corresponding infrared sensor and operation amplifier. The infrared light is emitted from a GaAs diode to luminate the printing ink roller and the reflected infrared light is detected by an infrared sensor close by. The infrared sensor converts the light signals into electronic signals. The operation amplifier tunes up the electronic signals to a level that is within the operation range of the process hereafter.

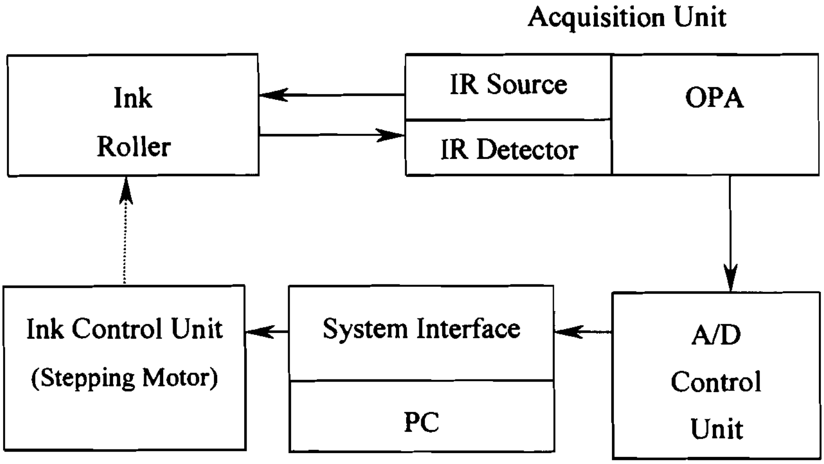

Figure 3. System Configurations

In the operation environment such as printing press, the infrared light source is exposed to the deviation of temperature, humidity and vaporized solvent. Consequently, a stable and durable infrared light source with highly-directional and narrow bandwidth is desirable for this application. Nippon electronics' EL-1KL3 infrared LED was selected under such criteria.

The EL-1KL3 infrared LED is manufactured from gallium arsenide (GaAs). It radiates infrared light at the wavelength between 900nm and 1000nm with peak wavelength at 940nm as shown on Figure 4. It has a glass lens top to provide good directional focus and metal shell to disperse heat.

The SP-1KL photosensor is suggested by the manufacturer to function as the corresponding infrared light detector for EK-1KL3. Its spectral sensitivity is ranged from 400nm to 1050nm with peak wavelength at 900nm as shown in Figure 5. Since its responding bandwidth also covers the visible band, increasing the intensity of the infrared light source and reducing the stray visible light is desirable to increase the signal to noise ratio (S/N) of the detected signal. This is achieved by tuning the intensity level of the infrared light higher and putting the SP-1KL photosensor close to the EL-1KL3 LED in a metal container, which also blocks away the unwanted light and dust.

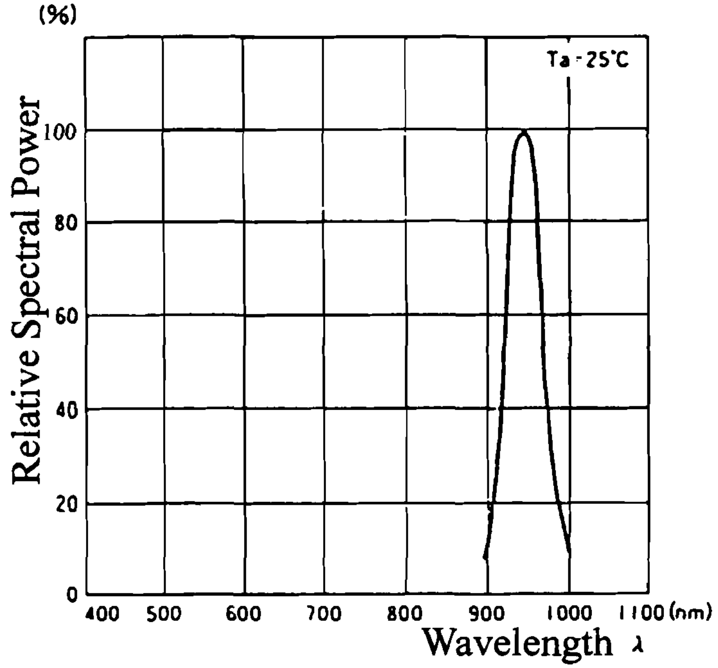

Figure 4. Relative Spectral Power Distribution of EL-1KL3 LED.

The data acquisition unit also contains the operation amplifier circuit to tune up the system for proper operation. According to the data book, the SP-1KL photosensor responds linearly to the stimulus only in the range between 0.6 uA and 130 uA. Correspondingly, the input current on the EK-1KL3 LED is set to the level such that the maximum output current (when no ink on the roller) of SP-1KL is 100 uA and the minimum current is 0.8 uA. This would ensure that the amount of the optoelectronic current is linearly related to the amount of ink on the roller.

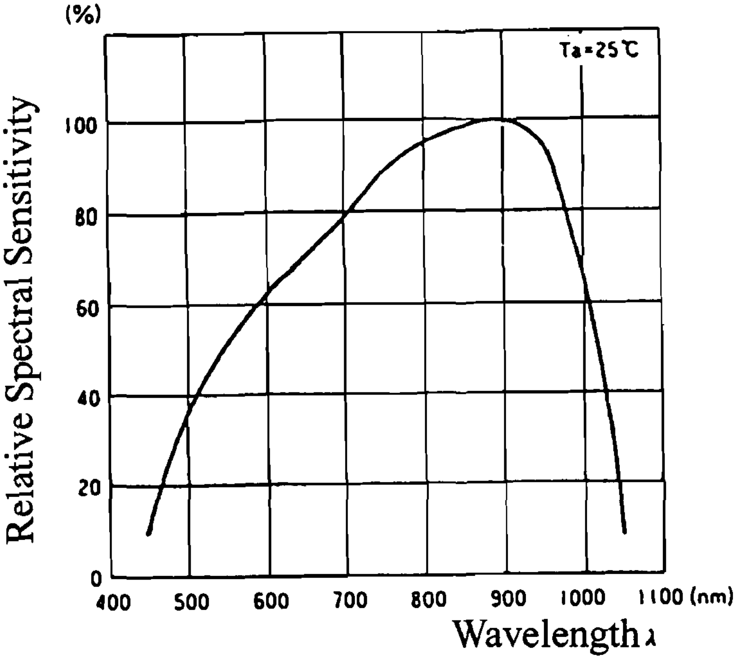

Figure 5. Relative Spectral Sensitivities of SP-1KL Sensor.

Analog to Digital Conversion Unit

The main function of the analog to digital (A/D) conversion unit is to convert the analog voltage from data acquisition unit into digital signal as the input to digital computer. The A/D conversion circuit first regulates the analog voltage from between 0 to 12 V to between 0 and 2.55 V and then converts it to the range between 0 to 255 discrete digital counts. The circuit can perform 3000 conversion per second and with access time of 135 ns. A voltage meter is also installed to monitor the input voltage level from the output side of the data acquisition unit. The A/D conversion unit is shown as Figure 6.

Process Unit

The process unit is based on a generic microprocessor personal computer. An interface card was designed to obtain the digital signal from the A/D unit. Software program was developed to provide the user interface and to perform the necessary computation as well as to generate the control signal for the system to function. The complete system is shown in Figure 7.

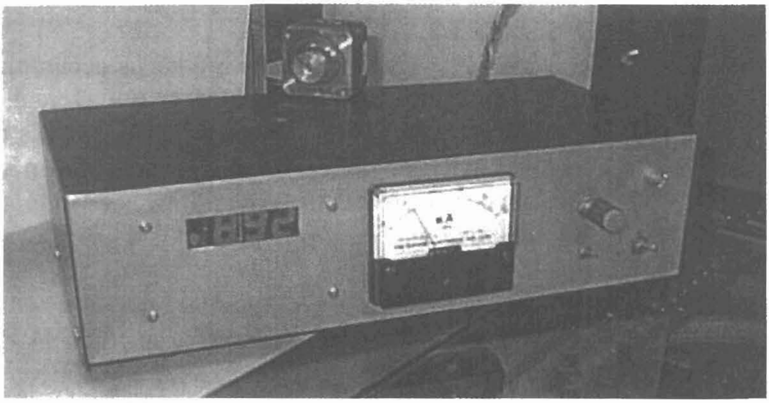

Figure 6. Analog to Digital Conversion Unit

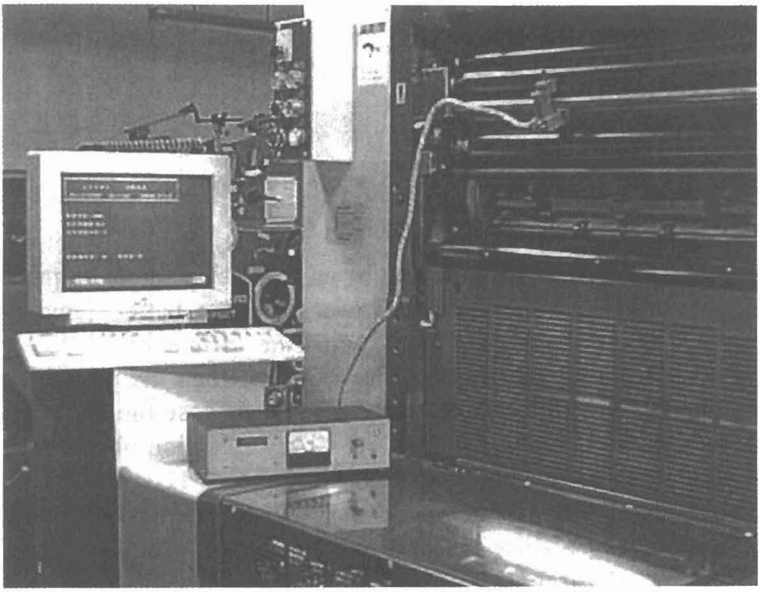

Figure 7. Complete System in Testing Setup.

The software program predefined values, the interface for the user to set several values as the followings:
1. Number of samplings to be averaged.
2. Plus and minus limits from the target ink value.
3. Numbers of over limit allowance for the system to alarm.
4. System parameters for the operating system.

According to these constant values, the software keeps accumulate the digital counts from the A/D unit and then computes the average to compare with the target digital count. When the difference exceeds the limit, the over-limit counter will be incremented by one. When the number of over-limit occurrence is greater than the allowance value, the alarm sequence will be activated and control signal will be sent to the step motor for correction.

The target digital count can be dissimilar for different color ink due to the spectral absorption difference. Therefore, some adjustment on the circuit to tune up the signal range is necessary for individual ink. This can be done by adjusting the reference voltage on the A/D circuit or by repositioning the infrared unit. The user interface would also display the digital count reading under current setting to aid the adjustment and the current reading can be recorded as the target digital count as user desires.

Ink Control Unit

A permanent magnet stepping motor was used to control the motion of the ink key. It was driven by an excitation signal output from a computer. If the ink density is lower than the target density, the stepping motor will rotate clockwise until the difference of density is diminished. If the current ink density is higher than the target density the stepping motor will rotate counterclockwise to lose the ink key until the ink density back to the target level. The resolution of the stepping motor is 1.8 degree per step in this experiment. The results of this automatic ink key adjustment system showed that the infrared detector was available for a precise measure on the ink film thickness and the rotation of stepping motor had a linear response to the difference of target density and current density.

Results and Discussion

Various tests were performed to ensure that the printed ink density is controlled by the system correctly and steadily under various conditions, such as different color inks and under influence of stray light.

Figures 8-11 show the relation between digital count recorded by the system and the measured density values for individual ink. For yellow ink, the recorded digital counts are between 172 and 212. The measured density on the printed paper is ranged between 2.10 and 0.24. The effective resolution of the system for the yellow ink is (2.10 - 0.24) / (212 – 172) = 0.0465 of density unit per digital count. The test results for all four inks are summarized in Table 1. It is noticed that all the values are within the normal operational range and the relationship between the measured density and recorded digital count is mostly in a linear fashion except in the darker area of the black ink. The system resolution for density per digital count is also lower for the black ink. Since the absorption bandwidth of the black ink is not selective through out the full bandwidth, the reflected signal might be weaker comparatively, consequently, results in a lower digital count. It is suggested that the probing intensity for the black ink should be increased for such type of system, which might also reduce the non-linearity problem as seen in the higher density area of the black ink.

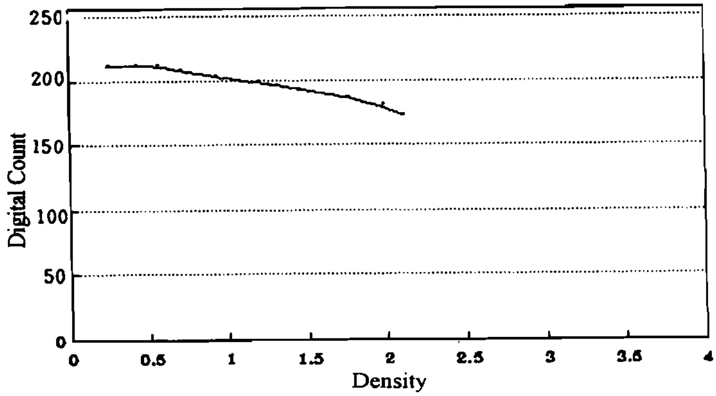

Figure 8. The Measured Yellow Ink Density vs. Recorded Digital Count.

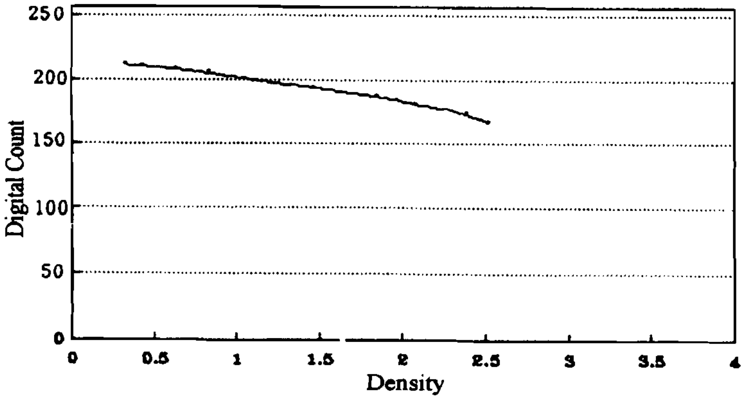

Figure 9. The Measured Magenta Ink Density vs. Recorded Digital Count.

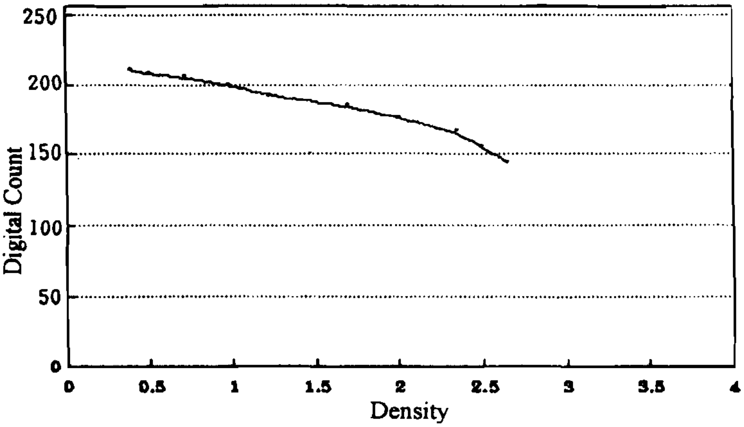

Figure 10. The Measured Cyan Ink Density vs. Recorded Digital Count.

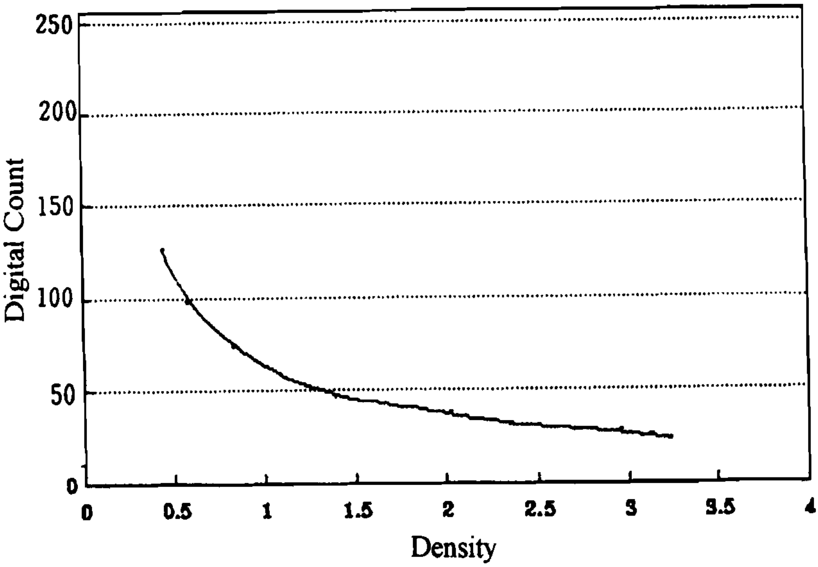

Figure 11. The Measured Black Ink Density vs. Recorded Digital Count.

Table 1. List of System Resolution for Various Inks

	Y. Ink	M. Ink	C. Ink	K. Ink
Max. Digital Count	212	211	210	126
Min. Digital Count	172	166	144	23
Measured Max. Density	2.1	2.51	2.64	3.23
Measured Min. Density	0.24	0.32	0.38	0.44
System Resolution	0.0465	0.0487	0.0342	0.0271

The influence of stray light was simulated from a 60W/110V tungsten light in various distance. As indicated in Figure12, the reading from the stray light is under 10 when it is more than 1 meter away. With such a small number, the influence is less significant compared with the signal level in Figures 8-11, and if the unwanted light source is steadily present, it might become the dark current included in the target value.

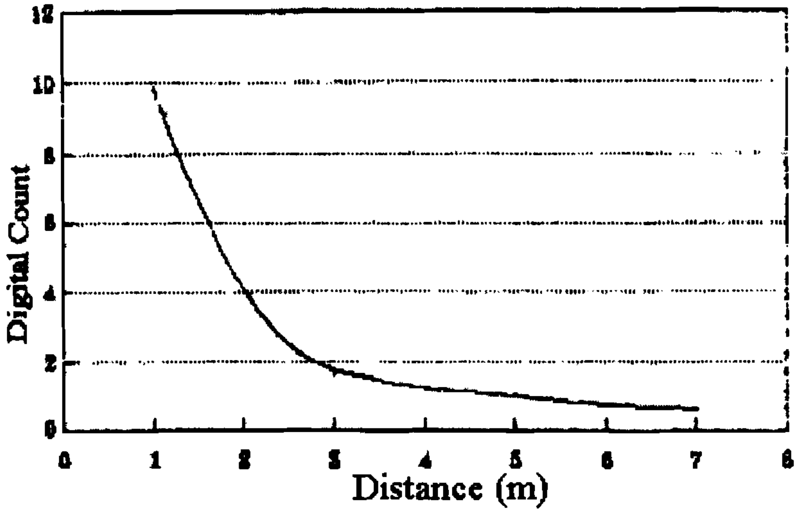

Figure 12. Result of Stray Light Test.

Conclusion

A stable ink supply is highly desirable in a printing system, however, the assessment of the ink amount is usually statically done by measuring the ink density on the printed paper. A real time approach is developed in this study to control the ink supply on the press. A microprocessor-based system aided with infrared technology was implemented to correlate the digital signal with ink density thus to control the ink supply. The results indicate that a linear relationship between the system's detected signal and the measured ink density can be achieved by this system. Consequently, the measurement of the ink density on the press can be performed in the real-time fashion. The system's reading was further used as the starting reference for feedback control by the software. A step motor was used to control the ink key for adjusting the ink supply, which completed the control loop for the whole system.

The stability of a press can be judged by the variation of solid ink density between each press. In general, a density variation between the interval of ± 0.1 to 0.15 can be considered as subordinate class. A density variation interval of ± 0.05 to 0.1 is considered as good quality. A high quality press should control the density variation interval of ± 0.025 to 0.05. In this research, the system resolution is achieved under density of 0.05 per digital count for each color of ink. Therefore, it's capable to control the press to high quality level.

This study has demonstrated the feasibility of applying infrared technology to the real time ink control. Furthermore, it is possible to implement this approach on an ASIC chip and to install it on each ink key unit which can improve the controllability on the press greatly.

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