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Method and apparatus for measuring the droplet frequency response of an ink jet printhead

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ABSTRACT

To speed up the printing speed of an inkjet printer, the manufacturers normally focus on increasing the droplet frequency response. Hence, it has become a very important technique to measure the droplet frequency response of an inkjet printhead. A magneto-electric method is proposed to measure the droplet frequency response. The magneto-electric apparatus contains a metallic detecting plate and a magnetic ring with a gap of about 100μm filled with a nonmagnetic insulating material. The magnetic ring itself is made of a high-permeability alloy consisting of about 78% nickel and 22% iron. When an ink drop jetted from a nozzle makes a contact with the metallic detecting plate, which is perpendicular to the nozzle plate of a printhead, a current is conducted through the detecting plate immediately, and detected as a portion of expected signal. The expected signal is then processed by a signal processing circuit for counting the number of jetted drops, and determining the maximum droplet frequency response of the inkjet printhead as a function of the driving frequency of an applied voltage across the printhead.

Keywords: Frequency response, magneto-electric method

INTRODUCTION

For most commercial inkjet printers, printing graphics and documents is normally carried out by the printhead. In principle, a thermal bubble printhead of an inkjet printer heats up the ink and vaporizes the ink to form ink bubbles by converting electric energy into heat. The printhead then jets the ink drops, which are developed from the ink bubbles, onto a medium surface through spouts. In order to speed up the printing efficiency of an inkjet printer, the manufacturers normally focus on increasing the droplet frequency response. That is, the droplet frequency response indicates the printing speed of an inkjet printer. Hence, how to measure the droplet frequency response of an inkjet printhead has become a very important technique in inkjet printer manufacture.

MEASUREMENT METHOD AND EXPERIMENTAL APPARATUS

The droplet frequency response is obtained by comparing the detected actual jetting frequency of an inkjet printhead with the driving frequency actually applied to the inkjet head. The maximum droplet frequency response of the inkjet printhead can be measured by checking the matching between different driving frequencies and the actual responding jetting frequencies. Since the ink bubbles are generated from the printhead in a frequency varied from several kilo-Hertz (kHz) to several tens kHz, it is impossible to detect the actual droplet frequency response through a regular image snapping system. Even though utilizing a high-speed camera is capable of catching the actual droplet frequency response of an inkjet printhead, and then, to determine the droplet frequency response of the inkjet printhead. However, it is not cost effective. Hence, some apparatuses and methods have been developed for the purpose of measuring droplet frequency response of an inkjet printhead, such as those disclosed by US patent number 4,484,199[1] and US patent number 4,590,482[2].

The schematic cross-sectional diagram of a conventional measuring apparatus for determining the droplet frequency response is illustrated in Fig.1. As seen from Fig.1, a planar detecting electrode is placed parallel to a metallic nozzle plate,

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and a voltage is applied across the detecting electrode and the nozzle plate. The detecting electrode and the nozzle plate are not electrically connected, though the distance between them is quite short. The distance is less than 100 μm. Once an ink drop is jetted by the nozzle plate through nozzle, the ink drop forms an electric conduction between the detecting electrode and the nozzle plate before the ink drop totally leaves the nozzle plate. A series of electric conduction formed by continuously jetted ink drops out of the nozzle plate can be detected by an attached electronic circuit (not shown in figure) for obtaining the forming frequency of ink drops. However, ink drops are easily stuck within the narrow space between the detecting electrode and the nozzle plate, and that leads to an error reading on the forming frequency of ink drops while a detecting process is performed.

The schematic cross-sectional diagram of another conventional measuring apparatus for determining the droplet frequency response is illustrated in Fig.2. Referring to Fig.2, a pair of electrodes is placed between the nozzle plate and the detecting electrode, wherein a high voltage is applied across the electrodes to provide a high-voltage electric field. While an ink drop jetted by the nozzle plate passes through the electrodes, the ink drop is charged. An electric signal can then be detected at the detecting electrode after the charged ink drop hits the detecting electrode. By counting the number of the electric signals within a period of time, the forming frequency of the ink drops is obtained. An ink drop, which is about 100 pico liters (pl) in volume, is possibly broken into several sub-drops while the ink drop passes through the high-voltage electric field, says exceeding 1000 volts. Therefore, the detected frequency counting at the detecting electrode is interfered by the noise signals given by the sub-drops.

A magneto-electric method is proposed to ensure a more precise measurement on the droplet frequency response, which does not encounter the problems of noise signal and error reading as mentioned previously. The magneto-electric apparatus for measuring the frequency response of ink drops contains a metallic detecting plate and a magnetic ring both placed under the nozzle plate, as shown in Fig.3A and Fig.3B. The detecting plate is perpendicular to the nozzle plate. In order to prevent an erroneous reading caused by stuck ink drops gathering on the detecting plate, the lower section of the detecting plate is designed to be capable of draining ink drops efficiently. Since the ink drops are formed at a pretty high forming frequency, from several kHz to several tens kHz, an erroneous reading is possibly obtained if the measured ink drops can not be efficiently drained. According to the foregoing consideration, the lower section of the detecting plate, for example, is made to be a metallic net-like structure, or a plate with a sharp corner pointing downward as shown in Fig.4. With a net-like structure or a sharp-corner shape, ink drops dropped on the detecting plate tend toward getting together as a larger drop, which is easily drained from the detecting plate.

As seen from Fig.3B, the magnetic ring has an opening toward the detecting plate, wherein the magnetic ring is attached to the detecting plate with the side arms aside the opening. The plane circled by the magnetic ring is perpendicular to the detecting plate, and parallel to the ground. The magnetic ring is, for example, an about 0.3-mm-thick lamination consisting of high-permeability material films or high-permeability alloy films. The selected high-permeability alloy can be an alloy of about 78% nickel and about 22% iron or other alloys with the similar properties. The selected high-permeability material can be ferrite, or other materials with the similar properties. The air gap of the magnetic ring is about 100 to 150 μm.

As seen from Fig.4 and Fig.3A, an insulating layer is placed between the nozzle plate and the detecting plate to prevent unnecessary electric conduction between the nozzle plate and the detecting plate. The insulating layer is about tens of microns to 100 μm in thickness. While a detecting task is performed, the measuring apparatus consisting of the insulating layer, the magnetic ring and the detecting plate is moving along the nozzle plate. The insulating layer is also used here to ensure the minimum distance between the detecting plate and the nozzle plate is fixed to a pre-determined distance, about the thickness of the insulating layer. The distance between the nozzle plate and the detecting plate can be reasonably adjusted and has to be short enough, so that an ink drop jetted from the nozzle can still make an electric conduction between those two plates before it drop off from the nozzle plate. All detected electric signals are output through a signal wire, which is electrically connected to the detecting plate, to a signal processor (not shown in figure). The measuring apparatus also contains a holding apparatus (see Fig.3A), and a supporting arm (see Fig.4). The holding apparatus is used to hold the magnetic ring, and the supporting arm is used to support and move the entire measuring apparatus.

The method for measuring the droplet frequency response by utilizing the foregoing measuring apparatus is based on the magneto-electric principle. As shown in Fig.3A, once a detecting task is started, a voltage is applied to the nozzle plate through a probe (not shown in figure). The voltage is about 30 volts and is capable of providing a current that is no higher than 100mA while a close loop is formed. When an ink drop is jetted from the nozzle, before the ink drop totally drops off from the nozzle, it forms an electric conduction between the nozzle plate and the detecting plate. As a result, a current I then flows through the detecting plate.

According to the Lenz's law, an induced magnetic field, which relates to the variation of current, is then generated by the formation of current I flowing through the detecting plate. Since the direction of current I is parallel to the detecting plate, the magnetic lines of force of the induced magnetic field generated by the show-up of the current I are perpendicular to the detecting plate. Therefore, the magnetic ring has to be placed in the position that the area circled thereby is perpendicular to the detecting plate in order to sense the induced magnetic field.

As soon as the ink drop totally drops off from the nozzle, an induced current I' flowing in the same direction as the current I is generated by the magnetic ring accordingly to the Lenz's law. Through the signal wire, the variation of voltage and current over the detecting plate within a time frame is fed to a signal processing routine (not shown in figure) to be further processed.

EXPERIMENTAL RESULTS AND DISCUSSION

The waveform of a detected electric signal is illustrated in Fig.5. The x-axis represents time and the y-axis represents the voltage of the detected electric signal at a corresponding time. The detected electric signal includes two segments, a fore-signal happening within the time frame $T1$ and a post-signal happening within the time frame $T2$, wherein the fore-signal is corresponding to the closed-loop current I, and the post-signal is then corresponding to the induced current I'. The time frame starts at when the ink drop jetted by the nozzle begins to make a contact with the detecting plate, wherein a portion of the ink drop, contacting interface, is connected to the detecting plate while a contact is made. The area of the contacting interface is increased within the time frame, and reaches its maximum at the end of the time frame, that is, the ink drop is dropped off completely from the nozzle. The post-signal detected within the time frame is the induced current I' generated by the magnetic ring due to the variation of current on the detecting plate. The induced current I' flows in the same direction as the closed loop current I does, and is gradually decreased as time goes. Without the presence of the magnetic ring, the only signal detected is the narrow and sharp pulse as shown in the time frame of Fig.5 that is difficult to detect. Therefore, the measuring apparatus increases the sensitivity of the measurement by adding a magnetic ring. While the printhead is operating by applying a driving signal, every ink drop jetted from the nozzle gives an electric signal detected by the magneto-electric measuring apparatus as shown in Fig.5.

A experimental result showing the electric signals detected by the measuring apparatus within a period of time is recorded as shown in Fig.6, wherein the x-axis represents time and the y-axis represents the voltage. The waveform signal in Fig.6 can be further processed to obtain a number indicating the forming frequency of ink drops at the nozzle plate. By checking the degrees of match between the forming frequencies of ink drops and the corresponding driving frequencies, the maximum droplet frequency response of the printhead of an inkjet printer can be obtained. The electric signals obtained on the detecting plate are sent to a signal-processing routine, and processed in a manner as shown in Fig.7.

After the electric signals are fed into the signal-processing routine through signal wire, a signal processor then picks up the valid signals first. The valid signals are next further adjusted and cleared by using a filter and a corrector to eliminate the noise signal. The results are digitized into digital signals. By using a display, such as a monitor, the digital signals are displayed on the monitor in the format of a waveform. Then, by checking the matching degrees of pairs of waveforms, each pair of waveforms consists of the forming frequency of ink drops and the corresponding driving frequency. The maximum droplet frequency response of the inkjet printhead is then obtained.

The insulating layer of the measuring apparatus prevent undesired electric conduction between the detecting plate and the nozzle plate, so the erroneous reading caused by improper electric conduction is avoided. The detecting plate perpendicular to the nozzle plate is capable of draining the dropped ink drops efficiently, so that no ink drop is stuck between the detecting plate and the nozzle plate that affect the detected results.

The magnetic ring of the measuring apparatus further enhances the detected signals, so the detected results are more easily to be processed for obtaining more precise results.

CONCLUSION

Based upon Lenz's law, a magneto-electric apparatus is designed to measure the frequency response of ink drops. The measurement sensitivity of the apparatus is drastically increases by adding a magnetic ring as compared to some conventional apparatuses. The magnetic ring further enhances the detected signals by generating an induced current, so the detected results are more easily to be processed for obtaining more precise results.

REFERENCES

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2. Robert R. Hay and Paul R. Spencer, "Nozzle test apparatus and method for thermal ink jet system," US patent No.4590482 (1986).

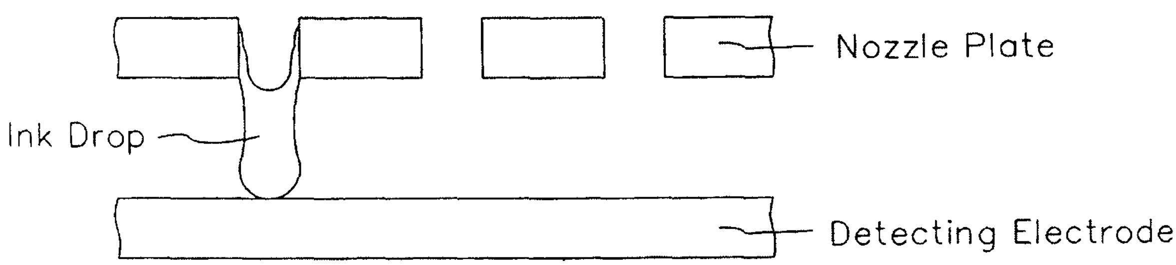


Fig.1 A schematic side-viewed diagram showing a conventional measuring apparatus for detecting the forming frequency of ink drops.

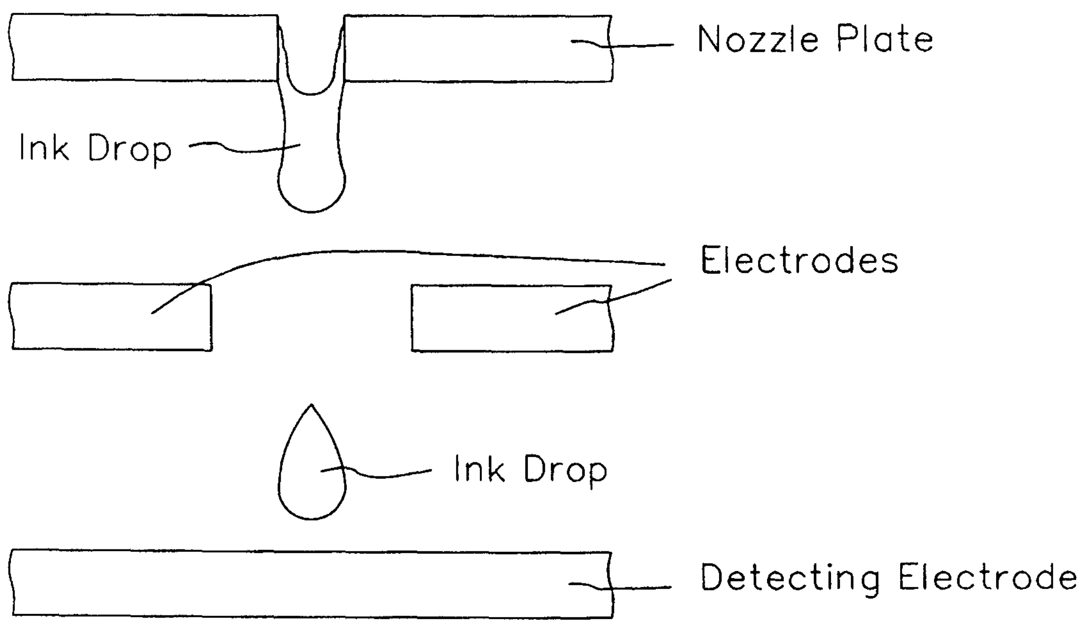
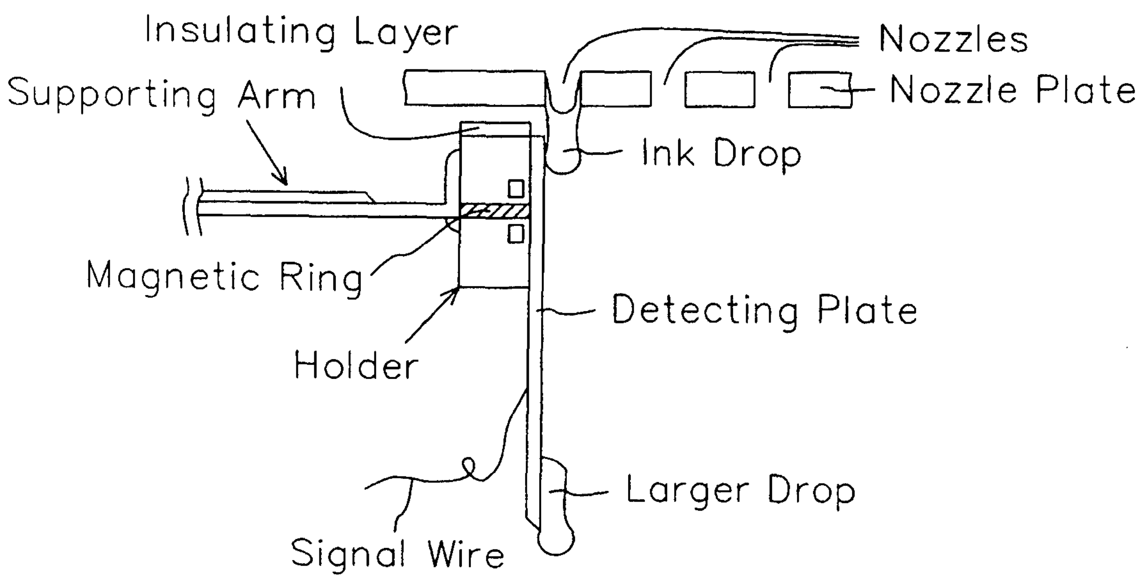
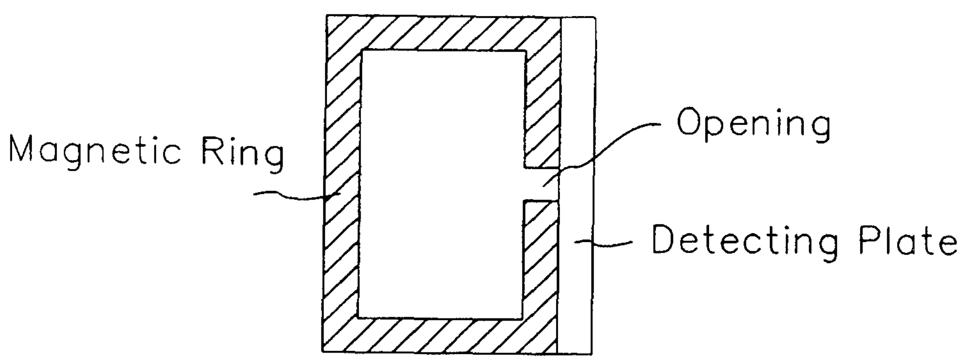


Fig.2 A schematic side-viewed diagram showing another conventional measuring apparatus for detecting the forming frequency of ink drops.



(3A)



(3B)

Fig.3 (A) A measuring apparatus for detecting the forming frequency of ink drops. (B) Magnetic ring

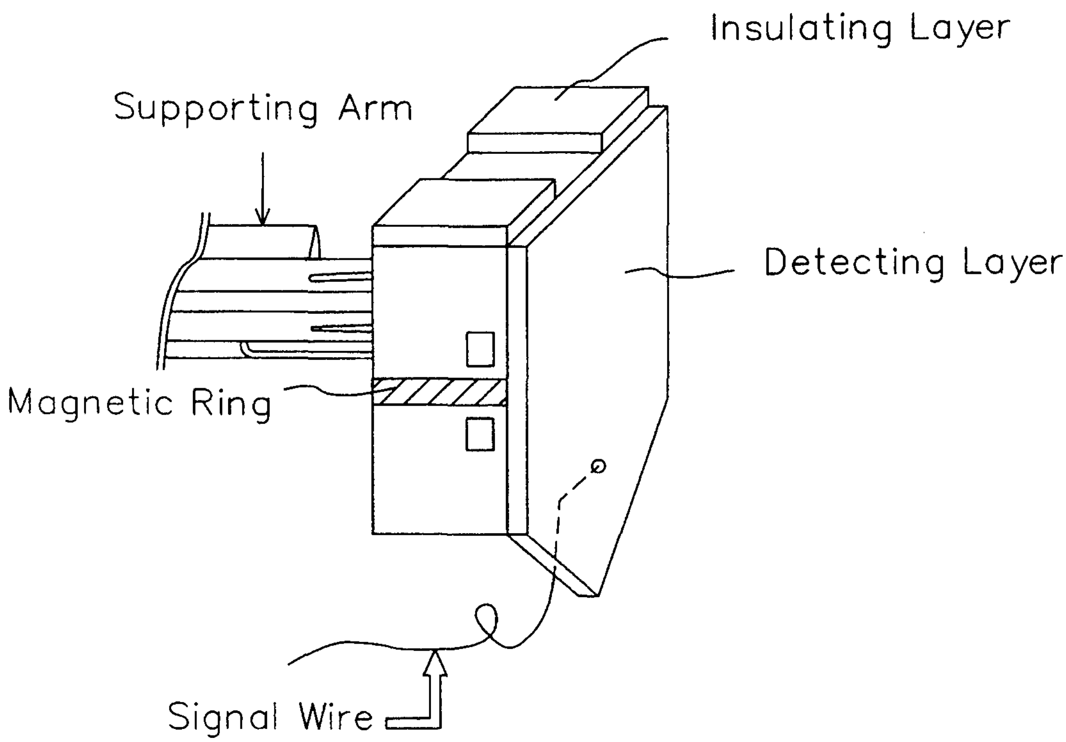


Fig.4 A schematic top-viewed diagram showing a measuring apparatus for detecting the forming frequency of ink drops.

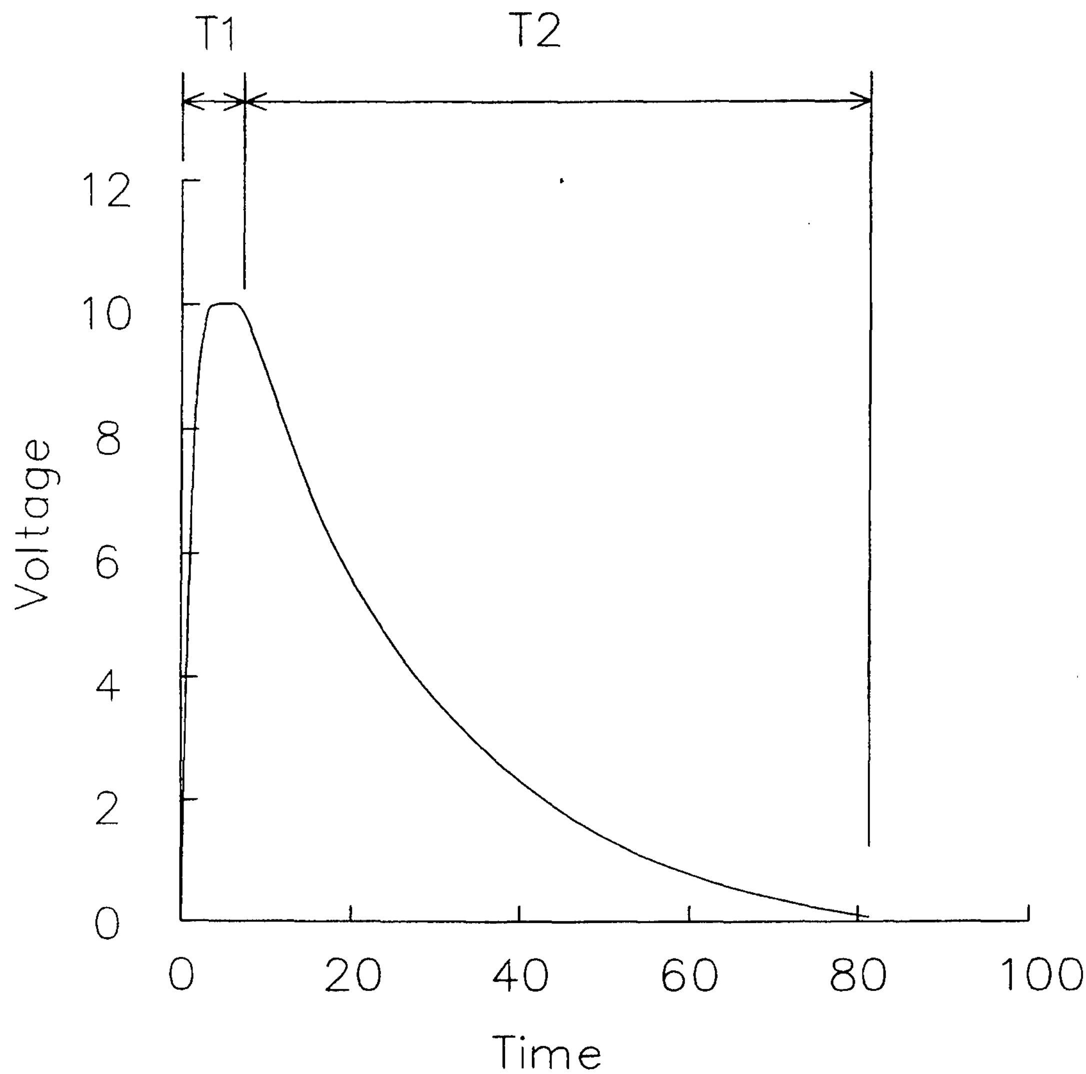


Fig.5 a waveform plot showing a signal detected by the measuring apparatus for detecting the forming frequency of ink drops. Time frame T1 Corresponding to the closed-loop current I. Time frame T2 corresponding to the induced current I'.

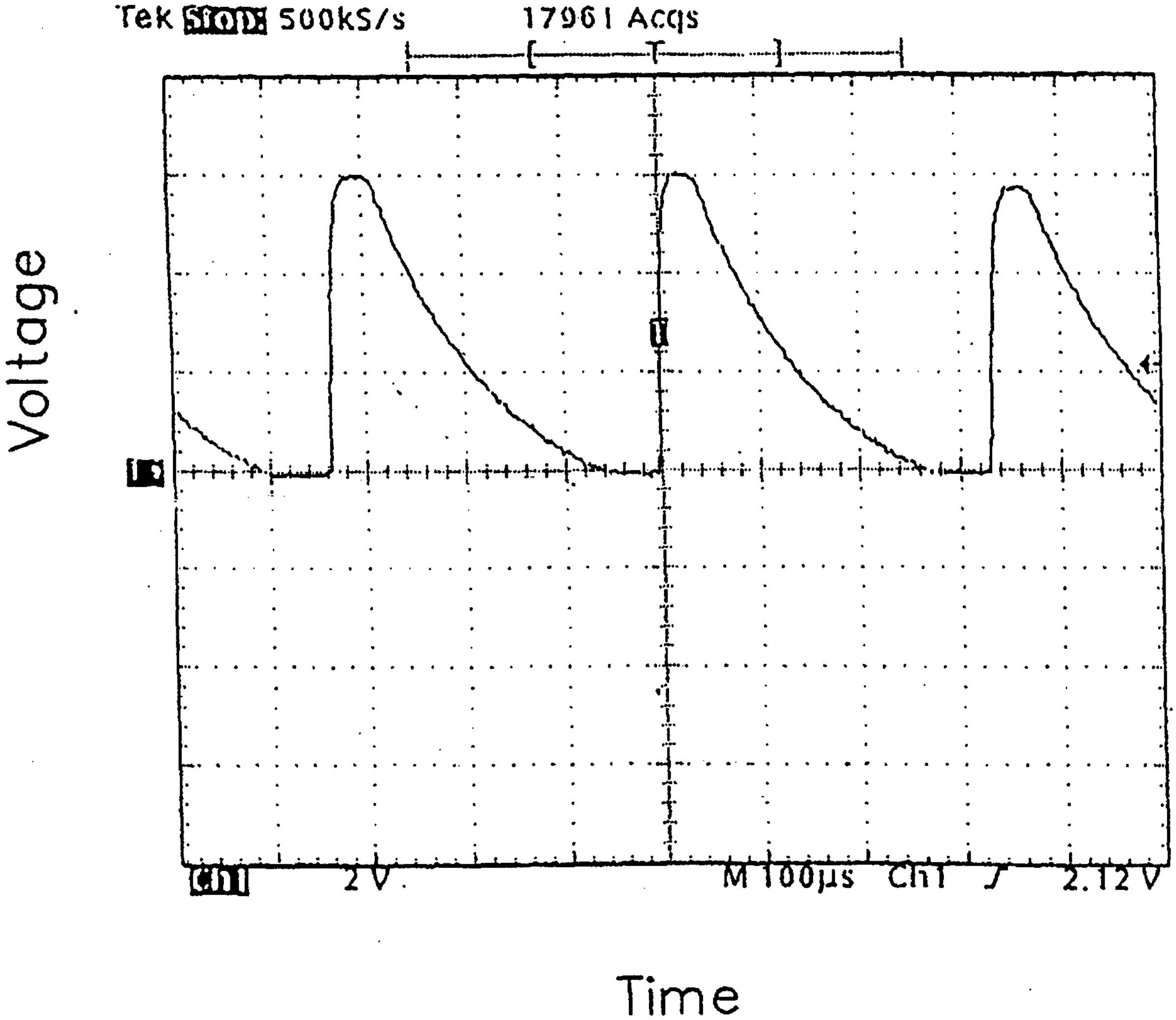


Fig.6 The actual signal measured by the magneto-electric apparatus for detecting the forming frequency of ink drops.

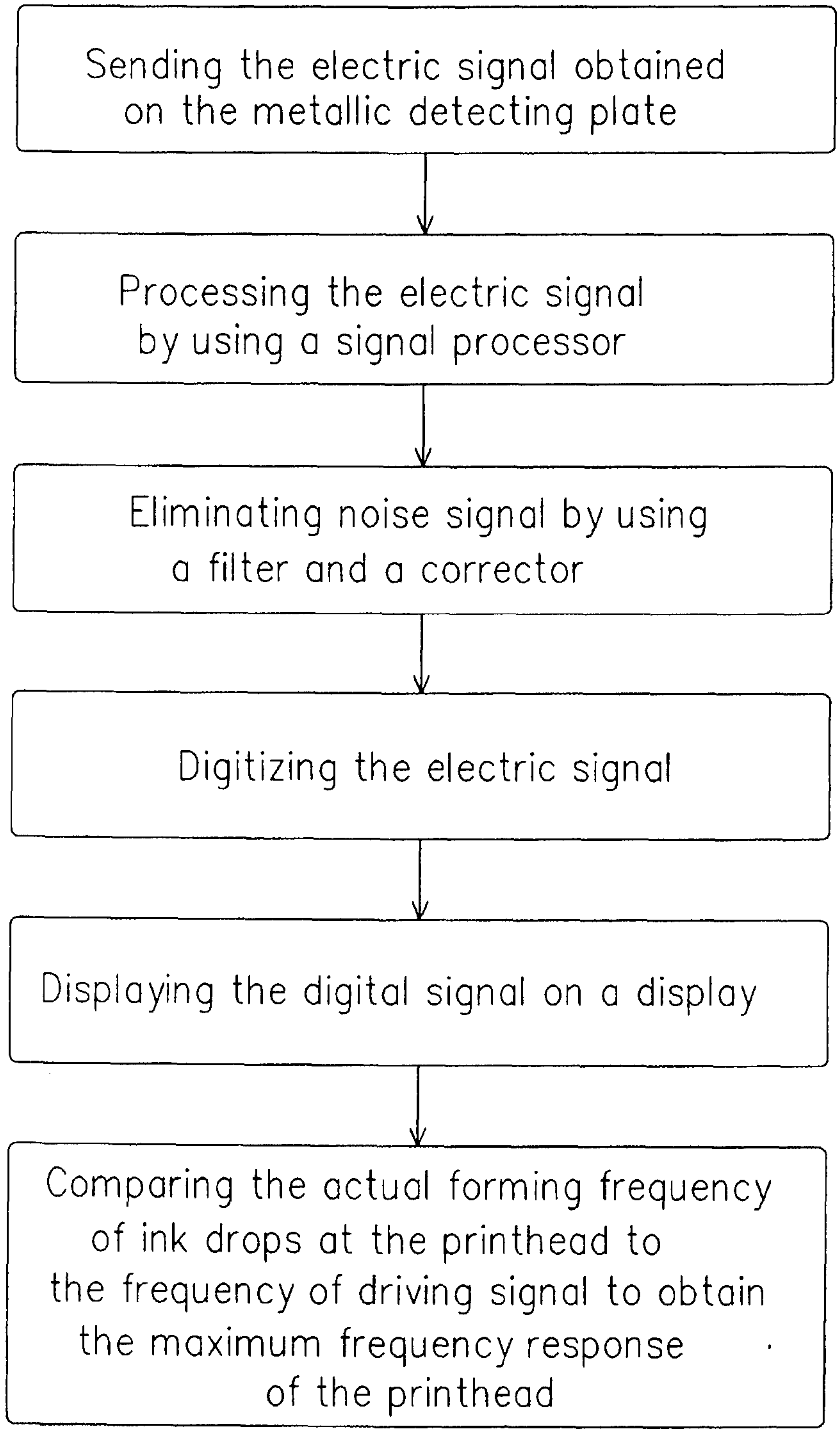


Fig.7 The flowchart of signal-processing routine used to process the signals detected by the measuring apparatus.