meteor

White Paper

PRINTHEAD WAVEFORMS:
ONE SIZE DOESN'T FIT ALL

The need for application-specific
inkjet printhead waveforms

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Overview

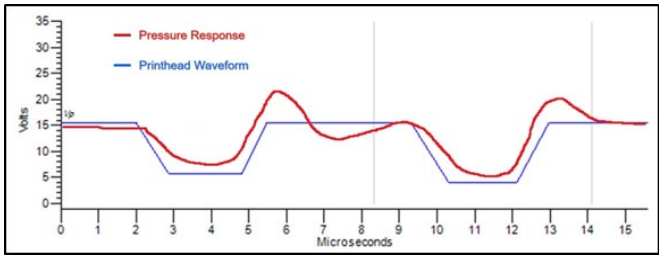
Anyone who has ever visited a tailor to purchase a bespoke suit knows that there is nothing quite like it. Styles and fabrics can be chosen to suit the occasion but it's the custom fit, shaped by a master craftsman, that makes all the difference. In close analogy, while an off-the-rack electrical waveform can be used to drive an inkjet printhead, bespoke waveforms offer so much more.

From the exceptional print quality requirements of commercial labels to the non-contact robustness needed for ceramic tile decoration, to the precision deposition capability demanded by printed electronics, tuning a waveform for specific combinations of printhead, fluid and substrate is the key to success for material developers, ink vendors and print system OEMs. Ink ejection as controlled by the printhead driving the waveform contributes just as much to image quality, print system productivity and jetting reliability as software interventions such as image profiling.

How waveforms are created and why they matter

Commercial piezoelectric (PZT) inkjet printheads come in many shapes and sizes. Although employing various proprietary methods to generate drops, they all operate in fundamentally the same way. When a voltage is applied to a PZT crystal within the printhead, the crystal changes shape. This shape change generates a pressure pulse within the printhead nozzle chamber resulting in the ejection of a drop.

The voltage which deforms the PZT crystal is created by electronics in the guise of a waveform (precisely timed voltage of variable amplitude). The shape of this waveform is crucial to printhead operation and is dictated both by the architecture of the printhead and the properties of the fluid. Ink parameters such as solvent composition, solids content and viscosity heavily influence the pressure response.



Printhead waveform and resultant pressure response for two sub drops.

Standard vs bespoke waveforms

Standard waveforms are commonly available from ink suppliers or printhead manufacturers. While adequate, these waveforms are rarely optimised to meet the demands of specific applications. They may not, for example, yield the required laydown for a given substrate or have poor linearity of response, making image management difficult. As an example, colour gamut, saturation, linearisation, coalescence and wetting effects on gloss substrates can prove especially challenging. Perhaps surprisingly, standard waveforms may also perform differently across colours in an ink set, imposing additional image quality and colour registration complications. Even inks with only slightly differing pigment and surfactant packages may exhibit dissimilar acoustic responses due to differences in viscoelasticity or surface tension. Further problems may be encountered when drop velocities are not optimised for the specific application, especially in cases like direct-to-object printing where extended or varying throw distances are required. Non-optimised waveforms can even impact print system productivity and reliability. The generation of undesirable satellite drops can promote ink build-up and dripping resulting in increased maintenance.

No one "right" waveform

Waveform generation and grey level mapping are performed either within the printhead or by way of external electronics.

There are advantages and disadvantages to each approach which balance the trade-offs of complexity, cost, heat dissipation and flexibility in addressability of voltage and timing parameters.

Fundamental factors to consider when determining the shape of a waveform include drop volume, drop velocity, productivity and reliability.

Drop Volume

Drop volume is one of the first characteristics considered when specifying a print system. Greyscale is built by applying multiple pulses within a waveform to eject drops of different sizes. Each drop must be ejected with enough energy to catch and coalesce with, but not perturb, preceding drops. Additionally, for precise control of laydown and colour gamut, drop volume linearity is important across grey levels.

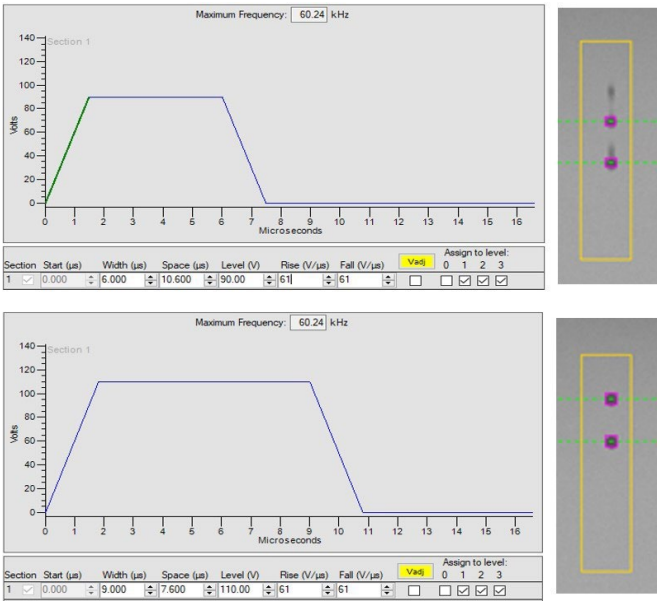
Drop Velocity

Optimising waveforms to prioritise velocity may

sacrifice elements of control over drop formation and the creation of small, unwanted satellites. Small drops can take longer in flight than large drops, during which time the substrate may have moved. A commonly pursued, but suboptimal "solution" is to overdrive standard waveforms with elevated voltages to increase laydown and throw distance, but this comes at the expense of system reliability and print quality.

Productivity

Maximum firing frequency is limited by the combined physical characteristics of the printhead and chosen fluid. Performance is further impacted by system parameters including the speed of the scanning carriage, web or object, the required size of the drop and resonance effects.



With a simple, single drop waveform, it is easy to illustrate how a drop can be ejected with a specific velocity and volume by way of two different waveform shapes. While the drop velocity and volume are the same in both cases, the quality of drop formation differs dramatically.

Reliability

Printhead waveforms play an essential role in print system reliability. Pulses can be designed to control

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ink build-up on the nozzle plate and even recover missing or deviating nozzles. With clever use of tickle pulses (waveforms which provide enough energy to keep the fluid moving within the nozzle without ejecting a drop), the length of time a system can be paused without problem can be extended.

Bespoke waveform development

At a minimum, bespoke waveform development should include the determination of drop volumes at various print frequencies for each fluid/waveform combination, the mapping of drop volume and velocity vs both drive voltage and print frequency, and the analysis of drop and ligament formation by observation of drops-in-flight. Also helpful is the investigation of fluid rheology to understand viscosity profiles, surface

tension, particle size and density in aid of potential fluid reformulation. And finally, the evaluation of open time and latency will help to impact jetting reliability, fluid build-up and misting.

To implement a bespoke printhead waveform, drive electronics must be acquired or developed which offer fine, digital control, ideally with the ability to produce

accurate waveforms that have good optimised pulses over a range of jetting loads. Simple, unsophisticated electronics are not up to the task.

Years of technical evolution have yielded a vast array of highly reliable printheads aimed at an endless stream of fluids in an ever-growing list of applications. In the matter of waveform optimisation, there is no substitute for understanding specific application requirements and when help is needed, calling on those who are masters in the art and science. Just as nothing compares with a well-tailored suit that is appropriate for the occasion, there is no one-size-fits-all for inkjet printhead waveforms.

About Meteor

Meteor Inkjet Ltd is the leading independent supplier of industrial inkjet electronics, software, tools and services. Working closely with all major industrial inkjet printhead manufacturers, Meteor offers production-ready solutions to printer OEMs and integrators worldwide.

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