An Examination of Ink Smoothing in a Web-Offset Printing Press

James M. Salacain

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AN EXAMINATION OF INK SMOOTHING IN A WEB-OFFSET PRINTING PRESS

by

James M. Salacain

A thesis submitted in partial fulfillment of the requirements for the degree of Bachelor of Science in the School of Photographic Arts and Sciences in the College of Graphic Arts and Photography of the Rochester Institute of Technology

Signature of Author.................................................. 4/15/85

Imaging and Photographic Science

Certified by.............................................................. 4/15/85

Edward Granger

Thesis Advisor

Accepted by.............................................................. 11/17/86

Supervisor, Undergraduate Research
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Date ................................................................. 4/16/85

ii
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ABSTRACT

A study was initiated which was designed to examine the
systems used for ink smoothing in a web-offset printing press. The
study evaluated several oscillating roller systems and
subjectively compared them using several criteria. It was found
that although some of the systems possessed a number of desirable
characteristics, none were of high enough overall quality to be
considered for implementation.
ACKNOWLEDGEMENTS

The author would like to thank the following for their help in the preparation of this thesis:

Dave Staley and the Product Support gang at Harris Graphics Corp.
Dr. Edward Granger of Eastman Kodak Co., for taking time away from his gliding to teach me about fourier transforms.
My classmates, for making the last four years bearable.
My entire family, without whom this would never have been possible.
The author, who would like to to take this opportunity to give himself a nice pat on the back.
DEDICATION

To my as yet unborn nephew/niece
and
to the wide open roads
of France.
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I. INTRODUCTION

Ten years ago, the typical web-offset printing press could produce up to 74,200 images, or signatures, per hour. Today, a web-offset press can produce over 88,600 signatures in the same time period. It goes without saying that when a typical press costs upwards of seven million dollars, that the faster a press can be run, the faster the printer will recoup his investment and begin to show a profit.

Increasing the speed of the press does, however, introduce certain problems. When the press is run at high speeds, each of the mechanisms of the press; the web, the inking system, etc., must run at correspondingly higher speeds. As is the case with any mechanical device, there is a limit as to how fast these mechanisms can be run before they begin to fail at their intended purpose. The inking system is one of the most important of these mechanisms.

The inking system is responsible for the introduction of the ink into the press and its subsequent transport to the printing plate. This makes it one of the most significant systems in the press with respect to the quality of the resulting printed image. If the inking system should deliver a non-uniform ink film to the plate, the resulting image may exhibit bleeding of the halftone dots, ink starvation in high density areas, or streaks running the length of the signature.
To better understand the problems associated with the inking system, a more comprehensive evaluation of its mechanism is in order.

It is seen on Figure #1 that the inking system of a typical press consists of an ink fountain, distribution rollers, oscillating rollers and inking rollers. The ink fountain, which consists of an ink reservoir, a set of ink blade blocks, and a fountain roller, is the mechanism which introduces the ink into the press. Because the plate may require more ink in some places than in others, the ink fountain must be able to regulate the ink-film profile, or the thickness of the ink film across the fountain roller. This is accomplished by a set of ink blade blocks. The ink blade blocks, shown in Figure #2, run the length of the fountain roller and serve to scrape the ink film to very precise thicknesses. Each of the ink blade blocks are individually adjustable so as to allow for the varying ink needs of the plate. It can be seen, from Figure #2, that the major drawback of the ink blade block system is that the resultant ink film, instead of being smooth, tends to have periodic ridges. These ridges will be referred to as ink film non-uniformities. Left unchecked, these non-uniformities would permeate the inking system and show up on the final printed image as pronounced streaks. This presents a serious problem. How can these non-uniformities be eliminated from the ink film without destroying the desired ink film profile?
Figure #1: The Inking System of a Typical Web-Offset Press

Ink Fountain

Oscillating Rollers

Distributor Rollers

Figure #2: The Ink-Blade Blocks

Ink-Blade Blocks

Fountain Roller Surface
Since the non-uniformities occur at a specific frequency, a system can be incorporated into the inking system which will filter out this frequency, and several of its harmonics, while passing all other frequencies. Looking at this hypothetical filter in frequency space, it can be seen, in Figure #3, that this filter, which is designed to be used in conjunction with ink blade blocks which are "b" wide, has a zero component at the frequencies of $1/b$, $2/b$, and $3/b$. Its behavior at all other frequencies is essentially unimportant, with the single caveat that the components for these frequencies should be as high as possible so as to allow for the most efficient passage of the ink film information.\(^5\)

Traditionally, this filtering has been accomplished by a special roller called an oscillating roller. This roller is in constant contact with two or more distributor rollers, and oscillates with a stroke equal to that of the width of a single blade block. The oscillating motion of this roller imparts to it a specific spread function which, when observed in frequency space, determines its filtering ability.

Returning, once again, to the problem of press speed, it can be seen that as the speed of the press increases, the rate of the oscillation of the vibrating rollers must also increase. This results in an increased lateral inertia imparted to the press by the oscillating rollers. When this inertia is sufficiently high, the press will begin to shake and its speed can no longer be increased.\(^6\)
Figure #3: Frequency Spectra of an Ideal Oscillating Roller
Some qualitative tests have been performed which attempted to decrease the inertia of the oscillating rollers so as to allow for increased press speed. These tests, because they did not take into account the spread functions of the oscillating rollers, resulted in an inefficient filtering, and hence, significant streaking of the image.

In this thesis, an organized attempt was made to examine the resultant ink profiles of various oscillating roller systems in an attempt to find a system which would have both good filtering characteristics and low inertia.
II. EXPERIMENTAL

A. Design of the Oscillating Roller Simulator

The first task of this project was to design an oscillating roller simulator. This device was a rather simplistic copy of conventional oscillating roller system. The design of the finished simulator is shown in Figure #4 and Figure #5. With this design, the oscillating system and the distributor rollers are driven by separate variable-speed drills so as to allow for a variety of configurations. Although this simulator has two sets of rollers, only one set was ever used. The operation of the simulator is as follows. The simulator is placed off of the base so that the rollers would be able to rotate freely. The distributor roller drive motor is adjusted to the desired speed, as is the rate of oscillation. The oscillator motor is then deactivated and a thin line of ink is applied to the now spinning distributor roller. When this ink film reaches an equilibrium width, usually about an inch wide, the oscillating roller motor is engaged. After allowing the distributor roller to complete ten revolutions, the simulator is then placed on the base and allowed to deposit the resultant ink film onto a sheet of clear acetate. The simulator is then be upended and cleaned. Care must be taken not to allow the second set of rollers to mar the fresh ink-film on the acetate.
Figure #4: Side View of the Oscillating Roller Simulator

Figure #5: Front View of Oscillating Roller Simulator
B. Development of Computer Model

A computer model was developed which was designed to simulate a very simple, but operational inking system. This system has a variable input, either a bar pattern or an edge, and can possess any number of oscillating and distributing rollers. The rate of oscillation and the stroke are adjustable. In the more advanced systems, the phase between multiple oscillators is adjustable. Each of the models developed are shown in Appendix A.

This model is based on 'the splitting rule' where at the interface of two rollers, the ink film splits equally between the two rollers. Thus, if one roller has an ink film which is .008 inches thick, and another roller has one .002 inches thick, upon coming in contact, each of the rollers would have a resultant ink-film .005 inches thick.

The model consists of a series of two-dimensional arrays, each corresponding to a different roller. The first dimension of the array is the length. Distributor rollers were assigned a length of 127 units while oscillating rollers were assigned 147 units. This was done so that the oscillating rollers would be capable of a maximum stroke of 21 units without losing contact with the ends of the distributor rollers.

The second dimension of the roller arrays corresponds to the circumference of the rollers. In this case the distributor rollers were assigned a circumference of 10 units while the oscillating rollers were assigned a value of 5. These values were maintained
for all of the models in the interest of simplicity.

At run-time, the model increments the second dimension of all of the arrays and initializes the first roller to a desired input pattern. It then calculates the ink transfers on a point by point basis for all of the rollers, sends all of the ink values for a single point on the circumference of the last roller to a line printer, and then repeats the process.

C. Verification of Computer Model

Before the computer model was used to evaluate any complex inking systems, the integrity of the model was first verified. This was done using the oscillating roller simulator. In order to say that the model was sound, the output of the computer model had to adequately match the output of the simulator for a given system configuration.

The first step was to set up the simulator with a specific configuration. The three parameters which determine the configuration of the system are the rate of rotation of the distributor roller, the frequency of the oscillating roller and the type of ink pattern to be smoothed. The various configurations tested are listed in Table #1. One run was performed for each of these configurations.
Next, the computer model was set up with the same configurations and, similarly, a single run was performed with each.

Lastly, a qualitative comparison of similar configurations was performed to determine the validity of the computer model.

<table>
<thead>
<tr>
<th>Rate of Rotation</th>
<th>Frequency of Oscillation</th>
<th>Input Ink Pattern</th>
</tr>
</thead>
<tbody>
<tr>
<td>60 rpm</td>
<td>0/dist. rev.</td>
<td>line</td>
</tr>
<tr>
<td>60 rpm</td>
<td>1/dist. rev.</td>
<td>line</td>
</tr>
<tr>
<td>60 rpm</td>
<td>2/dist. rev.</td>
<td>line</td>
</tr>
<tr>
<td>60 rpm</td>
<td>1/dist. rev.</td>
<td>edge</td>
</tr>
<tr>
<td>60 rpm</td>
<td>2/dist. rev.</td>
<td>edge</td>
</tr>
</tbody>
</table>
D. Evaluation of Oscillating Roller Systems

Five oscillating roller systems were evaluated. Each of the systems is depicted in Figure #6. Note that the labels in this Figure #6 refer to the names of the arrays in corresponding computer model.

The roller systems were evaluated according to the following criteria:

1. The uniformity of the resultant ink pattern.

2. The response of the system to an edge input pattern.

3. The relative inertia that each system would possess given that all systems would be made using similar parts.
Figure #6: Roller Systems.

System #1

INPUT → A → R → D → OUTPUT

Distributor
Rollers

System #2

→ A → R → R2 → D →

Oscillator
Rollers

System #3

→ A → R → D →

System #4

→ A → D →

System #5

→ A → D → R3 → R4 →
III. RESULTS

Figure #7: Simulator Run #1

Simulator Run #1: The distributor roller was adjusted to a speed of 60 rpm. The oscillator roller was deactivated. The input was a 1/4" line of paint. The scale of the figure is 1:0.64.
Simulator Run #2: The distributor roller was adjusted to a speed of 60 rpm. The oscillator roller was set to a frequency of 60 oscillations/minute. The input was a 1/4" line of paint. The scale of the figure is 1:0.64.
Simulator Run #3: The distributor roller was adjusted to a speed of 60 rpm. The oscillator roller was adjusted to a frequency of 120 oscillations/minute. The input was a 1/4" line of paint. The scale of the figure is 1:0.64.
Simulator Run #4: The distributor roller was adjusted to a speed of 60 rpm. The oscillator roller was adjusted to a frequency of 60 oscillations/minute. The input was an edge of paint. The scale of the figure is 1:0.64. Here the simulator run on the left is compared to the computer model on the right.
Simulator Run #5: The distributor roller was adjusted to a speed of 60 rpm. The oscillator roller was set to a frequency of 120 oscillations/minute. The input was an edge of paint. The scale of the figure is 1:0.64. Here, the simulator run on the left is compared with the computer model on the right.
Simulator Run #6: The distributor roller was adjusted to a speed of 60 rpm. The oscillator roller was adjusted to a frequency of 120 oscillations/minute. The input was an edge of paint. The scale of the figure is 1:0.64. Here, the simulator run on the left is compared with the computer model on the right.
Figure #13: System #1 Edge Profile

[Graph showing ink film thickness as a function of position for System #1 with an edge input.]

Note: 20 squares to the inch
Figure #14: System #2 Edge Profile
Figure #15: System #3 Edge Profile
Figure #16: System #4 Edge Profile
Figure #17: System #5 Edge Profile

Ink Film Thickness as a Function of System #5 with an Edge Input Position.

Squares to the inch
Figure #18: System #1 Bar Profile
Figure #19: System #5 Bar Profile
Figure #20: System #1 Output, Stroke = 21
Figure #21: System #2 Output, Stroke = 21
Figure #22: System #3 Output, Stroke = 21
Figure #23: System #4 Output, Stroke = 21
Figure #24: System #5 Output, Stroke = 21
IV. DISCUSSION

A. Computer Model Verification

Figure #7 shows the output from the simulator for a thin line input with no oscillation. It is evident that the simulator possesses a considerable spread function with out the need for an oscillating roller. This is due to the fact that the oscillating roller was allowed to ride directly on the distributor roller. In commercial presses, oscillating rollers are separated from the distributor rollers by a very small gap; about .001 inches. Without this gap, as is the case with the simulator, the oscillating roller tends to act like a squeegee, spreading the ink across the distributor roller. In fact, it keeps spreading the film out until the film is thin enough to fit between the rollers. As a result, the film in each of these runs is extremely uniform with respect to thickness. Further, the width of the film, at least for the thin line runs, is indicative of the amount of ink initially placed on the roller.

When the oscillating roller is activated, as in Figure #8 and Figure #9, rather than seeing a gradual and uniform decrease in ink film thickness, a rather sharp cutoff in the ink film is evident along with a periodic shift in the film placement. The sharp cutoff can be explained by understanding that the roller system was elevated off of the base by several layers of tape. As a result, the ink is either in contact with the acetate, or it
isn't. Where it is in contact, a significant deposit of ink is evident, and where it isn't, there is nothing. The shifting is evident because of the relatively slow rate of oscillation. It is seen in Figure #9 that the shifting is at a much higher frequency and is almost eliminated.

In Figures #10-12, comparisons are made between the edge response of the simulator and the edge response of the computer model. Figure #10 shows the low frequency oscillation case and it is seen that there is a significant correlation. One should note that when looking at the computer model print-outs that the numbers refer to the ink film thickness at a particular point on an output roller and that the output is a function of time from top to bottom. Figure #11 and Figure #12 draw similar comparisons for the high frequency case.

Because of the high correlation between the simulator runs and the computer model outputs, it is the opinion of this author that the computer model used in this thesis is valid.

B. Explanation of Plots

The graphs of Figures #13-19, although drawn as continuous functions, are plots of discrete data. As such, these plots are by no means empirical and are included in this thesis for the purpose of comparison only. Each family of curves represents a series of runs of the computer model where the stroke of the given system is
increased from a value of zero to the maximum value for the system. Figures #13-17 represent the response of the systems to an edge input while Figures #18-19 represent the response of systems #1 and #5 to a bar pattern input. Figure #16 represents the response of system #4 to alterations in the phase between its two oscillating rollers.

C. Explanation of Computer Model Outputs

The computer print-outs shown in Figures #20-24 represent the output of the given roller system as a function of time where time increases from top to bottom. The individual numbers represent the relative ink-film thickness at that given point on the output. Each of the outputs shown are the result of an edge input pattern with an oscillator stroke of 21. These are included in this thesis as a means of ascertaining the uniformity of the output of a given system.

D. Interpretation of Plots

Figure #16 shows the family of edge response curves for System #1. It is seen that the curve for a stroke of zero gives us a perfect edge. As the stroke is increased, it is evident that the response of the system gradually flattens out at the extremes but
remains very steep at the inflection point. The 'Stroke = 21 Step = 2' curve was designed to examine the case where the Oscillator frequency is doubled without altering the stroke. It is evident from this curve that increasing the frequency does tend to flatten out the curve but has little effect at the point of inflection.

System #2, as seen in Figure #14, exhibits far better smoothing characteristics than did System #1. Once again, the high frequency curve exhibits a significantly flattened response at the extremes but no decrease in slope at the point of inflection. Here again it is evident that, generally, the response of the system tends to flatten as the stroke is increased.

System #3, in Figure #15, tends to behave differently than the previous systems. The high frequency curve shows significant smoothing at the point of inflection. This may be explained by the fact that there is considerable error involved in mapping this discrete system onto a continuous plot. Regardless, this system exhibits the increased flattening with increased stroke.

System #5, in Figure #17, is certainly the most efficient system of the group. Its smoothing characteristics surpass those of all of the previous systems. This system would be capable of operating at half the stroke of the other systems with equal results.

Comparing Figures #18 and #19, The bar pattern response for systems #1 and #5 respectively, it is evident that while System #5 exhibits a very flat response for both the 21 unit stroke and the 11 unit stroke, System #1 shows remarkably little smoothing.
Looking at System #4, in Figure #16, an attempt was made to ascertain the effect changing the phase between oscillating rollers has on the smoothing mechanism. The case where there is no phase difference between the rollers has the weakest smoothing effect, while a phase difference of $2\pi$ has the strongest.

E. Interpretation of Computer Outputs

In looking at Figures #20-24 it becomes apparent why it was not considered feasible to determine the MTF of the various roller systems. It seems that the spread functions of the systems tend to change with time. Averaging the spread functions was not considered wise because the change in spread function was not due to a random error but due to the system itself. It is noticed that in Figure #20, that the spread function of System #1 seems to be directly related to direction of movement of the oscillating roller at any given time. If the roller is moving into the edge, the edge response becomes steeper, and if the roller is moving out of the edge, the edge response becomes flatter.

This rule is not as simple when examining multiple roller systems. In Figure #21, for instance, The action of the opposing oscillator rollers seems to decrease the shift slightly. However, it was observed at run time that the periodic shift of the edge response was most closely linked to the motion of the oscillating roller nearest the output roller.
System #3, in Figure #22, seems to have the most consistent edge response of all of the systems. It is marred only by a small shift which occurs during the change of direction of the rollers. This consistency could be due to the fact that the secondary oscillating roller is in contact only with the primary oscillating roller. The two rollers act to cancel out any inherent inconsistencies in the edge response.

Looking at System #4, in Figure #23, it is seen that the edge response for this system varies greatly with time. Once again, the periodic changes in the spread function seem to be caused by the oscillating roller nearest the output roller.

System #5, in Figure #5, attempts to counter the edge response problem by placing opposed oscillating rollers on each of the distributor rollers. Although the resulting edge response is very consistent, a periodic shifting is evident. This shifting seems to be linked with top oscillating roller on the output distributor roller.

F. Rating of Systems by Relative Inertia

Of all of the systems tested, System #1 has the worst inertial characteristics. Having only one roller, System #1 has no mechanism to counter the sudden change of momentum which occurs every time the roller changes direction. At high speeds, this system would be unacceptable.
Systems such as #2 or #3 are ideal because the opposed oscillating rollers are very close together and act to cancel each other out.

Systems such as #4 or #5 also act to cancel each other out, but because the opposed rollers are separated, torsional effects will be introduced when run at high speed. This will be especially true for System #5 which, having four oscillating rollers, possesses a significant mass.
V. CONCLUSIONS

Of all the systems which were evaluated, System #5 possesses the most efficient smoothing mechanism. This system however suffers from a time dependent spread function and a significant inertia. System #3 had the most desirable characteristics. These include a low inertia and a spread function which does not change significantly with time.

Generally, the smoothing characteristics of an oscillating roller system tend to increase with increasing stroke. Further, the most effective smoothing occurs when the phase between two oscillating rollers is $2\pi$. 
VI. REFERENCES

1) D.J. McCooey, Engineer at Harris Graphics Corporation, Product Support Group, personal communication on telephone, October 17, 1984.


5) Dr. E. Granger, Eastman Kodak Company, personal communication at the Rochester Institute of Technology, October 6, 1984.


VII. APPENDIX A: Computer Listings

10 DIM R(147,4) :rem This is the model for System #1
20 DIM A(127,9) :rem Here is where the arrays are
30 DIM D(127,9) :rem dimensioned and initialized
70 X = 4
75 XP = 1
76 Z = 9
77 ZP = 4
80 FOR S = 64 TO 127
90 FOR Y = 0 TO 9
100 A(S,Y) = 0
110 NEXT Y
120 NEXT S
130 FOR N = 1 TO 200
140 X = X + 1 :rem Rotate the Rollers
150 XP = XP + 1
160 IF X = 5 THEN X = 0
170 IF XP = 5 THEN XP = 0
180 Z = Z + 1
190 ZP = ZP + 1
200 IF Z = 10 THEN Z = 0
210 IF ZP = 10 THEN ZP = 0
215 PRINT N
220 FOR CNTCT = 0 TO 127 : rem Calculate ink transfers
230 IF CNTCT > 63 GOTO 250
240 A(CNTCT,Z) = 40
250 A(CNTCT,ZP) = (R((CNTCT+10-SHIFT),X) + A(CNTCT,ZP))/2
260 R((CNTCT+10-SHIFT),X) = A(CNTCT,Z)
270 D(CNTCT,Z) = (R((CNTCT+10-SHIFT),XP) + D(CNTCT,Z))/2
280 R((CNTCT+10-SHIFT),(XP)) = D(CNTCT,Z)
290 D(CNTCT,(ZP)) = D(CNTCT,ZP)/2
300 V = CNTCT
310 IF D(V,ZP) < 1 THEN LPRINT"0";:GOTO 420 :rem output
320 IF D(V,ZP) < 2 THEN LPRINT"1";:GOTO 420 :rem result
330 IF D(V,ZP) < 3 THEN LPRINT"2";:GOTO 420
340 IF D(V,ZP) < 4 THEN LPRINT"3";:GOTO 420
350 IF D(V,ZP) < 5 THEN LPRINT"4";:GOTO 420
360 IF D(V,ZP) < 6 THEN LPRINT"5";:GOTO 420
370 IF D(V,ZP) < 7 THEN LPRINT"6";:GOTO 420
380 IF D(V,ZP) < 8 THEN LPRINT"7";:GOTO 420
390 IF D(V,ZP) < 9 THEN LPRINT"8";:GOTO 420
400 IF D(V,ZP) < 10 THEN LPRINT"9";:GOTO 420
410 IF D(V,ZP) < 20 THEN LPRINT"*";:GOTO 420
420 NEXT CNTCT
440 IF SW = 0 THEN SHIFT = SHIFT + 1:IF SHIFT = 2 THEN SW = 1
450 IF SW = 1 THEN SHIFT = SHIFT - 1:IF SHIFT = -2 THEN SW = 0
460 NEXT N : rem calculate shift and repeat
10 DIM R(147,4): rem This is the model for System #2
20 DIM R2(147,4)
30 DIM A(127,9): Similar to model for System #1
40 DIM D(127,9)
80 X = 4
90 XP = 1
100 Z = 9
110 ZP = 4
120 FOR S = 0 TO 127
130 FOR Y = 0 TO 9
140 A(S,Y) = 0
150 NEXT Y
160 NEXT S
170 FOR N = 1 TO 200
180 X = X + 1
190 XP = XP + 1
200 IF X = 5 THEN X = 0
210 IF XP = 5 THEN XP = 0
220 Z = Z + 1
230 ZP = ZP + 1
240 IF Z = 10 THEN Z = 0
250 IF ZP = 10 THEN ZP = 0
260 FOR CNTCT = 0 TO 127
270 IF CNTCT > 63 GOTO 290
280 A(CNTCT,Z) = 40
290 A(CNTCT,ZP) = (R((CNTCT+10-SHIFT),X) + A(CNTCT,ZP))/2
300 R((CNTCT+10-SHIFT),X)=A(CNTCT,ZP)
310 R2((CNTCT+10-SHNEG),X) = (R((CNTCT+10-SHIFT),XP)+R2((CNTCT+10-SHNEG),XP))/2
320 R((CNTCT+10-SHIFT),XP) = R2((CNTCT+10-SHNEG),X)
330 D(CNTCT,Z) = (D(CNTCT,Z) + R2((CNTCT+10-SHNEG),XP)) / 2
340 R2((CNTCT+10-SHNEG),XP) = D(CNTCT,Z)
350 D(CNTCT,ZP) = D(CNTCT,ZP) / 2
360 V = CNTCT
370 IF D(V,ZP) < 1 THEN LPRINT"0"; GOTO 480
380 IF D(V,ZP) < 2 THEN LPRINT"1" ; GOTO 480
390 IF D(V,ZP) < 3 THEN LPRINT"2" ; GOTO 480
400 IF D(V,ZP) < 4 THEN LPRINT"3" ; GOTO 480
410 IF D(V,ZP) < 5 THEN LPRINT"4" ; GOTO 480
420 IF D(V,ZP) < 6 THEN LPRINT"5" ; GOTO 480
430 IF D(V,ZP) < 7 THEN LPRINT"6" ; GOTO 480
440 IF D(V,ZP) < 8 THEN LPRINT"7" ; GOTO 480
450 IF D(V,ZP) < 9 THEN LPRINT"8" ; GOTO 480
460 IF D(V,ZP) < 10 THEN LPRINT"9" ; GOTO 480
470 IF D(V,ZP) < 20 THEN LPRINT"*" ; GOTO 480
480 NEXT CNTCT
500 IF SW = 0 THEN SHIFT = SHIFT + 0:
510 SHNEG = SHNEG - 0: IF SHIFT > 10 THEN SW = 1
520 IF SW = 1 THEN SHIFT = SHIFT - 0:
530 SHNEG = SHNEG + 0: IF SHIFT <= -10 THEN SW = 0
540 NEXT N
10 DIM R(147,4) :rem Model For System #3
20 DIM R2(147,4)
30 DIM A(127,9):rem Similar to system #1
40 DIM D(127,9)
80 X = 4
90 XP = 1
95 XT = 3
100 Z = 9
110 ZP = 4
170 FOR N = 1 TO 200
180 X = X + 1
190 XP = XP + 1
195 XT= XT+1
200 IF X = 5 THEN X = 0
210 IF XP = 5 THEN XP = 0
215 IF XT = 5 THEN XT = 0
220 Z = Z + 1
230 ZP = ZP + 1
240 IF Z = 10 THEN Z = 0
250 IF ZP = 10 THEN ZP = 0
260 FOR CNTCT = 0 TO 127
270 IF CNTCT > 63 GOTO 290
280 A(CNTCT,Z) = 20
290 A(CNTCT,ZP)= (R((CNTCT+10-SHIFT),X) + A(CNTCT,ZP))/2
300 R((CNTCT+10-SHIFT),X)=A(CNTCT,ZP)
310 R2((CNTCT+10-SHNEG),X)=R((CNTCT+10-SHIFT),XT)+
      R2((CNTCT+10-SHNEG),X))/2
320 R((CNTCT+10-SHIFT),XT)=R2((CNTCT+10-SHNEG),X)
330 D(CNTCT,Z)=(D(CNTCT,Z)+R((CNTCT+10-SHIFT),XP))/2
340 R((CNTCT+10-SHIFT),XP)=D(CNTCT,Z)
350 D(CNTCT,ZP) = D(CNTCT,ZP)/2
360 V = CNTCT
370 IF D(V,ZP) < 1 THEN LPRINT"0";GOTO 480
380 IF D(V,ZP) < 2 THEN LPRINT"1";GOTO 480
390 IF D(V,ZP) < 3 THEN LPRINT"2";GOTO 480
400 IF D(V,ZP) < 4 THEN LPRINT"3";GOTO 480
410 IF D(V,ZP) < 5 THEN LPRINT"4";GOTO 480
420 IF D(V,ZP) < 6 THEN LPRINT"5";GOTO 480
430 IF D(V,ZP) < 7 THEN LPRINT"6";GOTO 480
440 IF D(V,ZP) < 8 THEN LPRINT"7";GOTO 480
450 IF D(V,ZP) < 9 THEN LPRINT"8";GOTO 480
460 IF D(V,ZP) <10 THEN LPRINT"9";GOTO 480
470 IF D(V,ZP) <20 THEN LPRINT"*";GOTO 480
480 NEXT CNTCT
500 IF SW = 0 THEN SHIFT = SHIFT + 2:
      SHNEG = SHNEG-Z:IF SHIFT>10 THEN SW = 1
520 IF SW = 1 THEN SHIFT = SHIFT - 2:
      SHNEG = SHNEG+2:IF SHIFT<-10 THEN SW = 0
540 NEXT N
10 DIM R(147,4): rem Model for System #4
20 DIM R2(147,4)
30 DIM A(127,9): rem Similar to System #1
40 DIM D(127,9)
80 X = 4
100 Z = 9
110 ZP = 4
115 ZT = 2
170 FOR N = 1 TO 200
180 X = X + 1
200 IF X = 5 THEN X = 0
220 Z = Z + 1
230 ZP = ZP + 1
235 ZT = ZT + 1
240 IF Z = 10 THEN Z = 0
250 IF ZP = 10 THEN ZP = 0
255 IF ZT = 10 THEN ZT = 0
260 FOR CNTCT = 0 TO 127
270 IF CNTCT > 63 GOTO 290
280 A(CNTCT, Z) = 20
290 A(CNTCT, ZT) = (R((CNTCT + 10 - SHIFT), X) + A(CNTCT, ZT))/2
300 R((CNTCT + 10 - SHIFT), X) = A(CNTCT, ZT)
301 A(CNTCT, ZP) = (A(CNTCT, ZP) + D(CNTCT, Z))/2
302 D(CNTCT, Z) = A(CNTCT, ZP)
310 R2((CNTCT + 10 - SHNEG), X) = (D(CNTCT, ZT) + D(CNTCT, Z))/2
320 D(CNTCT, ZT) = R2((CNTCT + 10 - SHNEG), X)
350 D(CNTCT, ZP) = D(CNTCT, ZP)/2
360 V = CNTCT
370 IF D(V, ZP) < 1 THEN LPRINT"0"; GOTO 480
380 IF D(V, ZP) < 2 THEN LPRINT"1"; GOTO 480
390 IF D(V, ZP) < 3 THEN LPRINT"2"; GOTO 480
400 IF D(V, ZP) < 4 THEN LPRINT"3"; GOTO 480
410 IF D(V, ZP) < 5 THEN LPRINT"4"; GOTO 480
420 IF D(V, ZP) < 6 THEN LPRINT"5"; GOTO 480
430 IF D(V, ZP) < 7 THEN LPRINT"6"; GOTO 480
440 IF D(V, ZP) < 8 THEN LPRINT"7"; GOTO 480
450 IF D(V, ZP) < 9 THEN LPRINT"8"; GOTO 480
460 IF D(V, ZP) < 10 THEN LPRINT"9"; GOTO 480
470 IF D(V, ZP) < 20 THEN LPRINT"*"; GOTO 480
480 NEXT CNTCT
500 IF SW = 0 THEN SHIFT = SHIFT + 1:
      SHNEG = SHNEG - 1: IF SHIFT > 10 THEN SW = 1: GOTO 530
520 IF SW = 1 THEN SHIFT = SHIFT - 1:
      SHNEG = SHNEG + 1: IF SHIFT <= -10 THEN SW = 0
540 NEXT N
10 DIM R(147,4): rem Model for System #5
20 DIM R2(147,4)
30 DIM R3(147,4): rem similar to System #1
40 DIM R4(147,4)
50 DIM A(127,9)
60 DIM D(127,9)
100 X = 4
110 Z = 9
120 ZP = 4
130 ZT = 2
140 ZB = 6
200 FOR N = 1 TO 200
210 X = X + 1
220 IF X = 5 THEN X = 0
230 Z = Z + 1
240 ZP = ZP + 1
250 ZT = ZT + 1
260 ZB = ZB + 1
270 IF Z = 10 THEN Z = 0
280 IF ZP = 10 THEN ZP = 0
290 IF ZT = 10 THEN ZT = 0
300 IF ZB = 10 THEN ZB = 0
310 FOR CNTCT = 0 TO 127
320 IF CNTCT > 63 GOTO 340
330 A(CNTCT,Z) = 30
340 A(CNTCT,ZT) = (R((CNTCT+10-SHIFT),X) + A(CNTCT,ZT))/2
350 R((CNTCT+10-SHIFT),X) = A(CNTCT,ZT)
352 A(CNTCT,ZB) = (A(CNTCT,ZB) + R3((CNTCT+10-SHNEG),X))/2
353 R3((CNTCT+10-SHNEG),X) = A(CNTCT,ZB)
360 A(CNTCT,ZP) = (A(CNTCT,ZP) + D(CNTCT,Z))/2
370 D(CNTCT,Z) = A(CNTCT,ZP)
380 R2((CNTCT+10-SHNEG),X) = (D(CNTCT,ZT) + R2((CNTCT+10-SHNEG),X))/2
390 D(CNTCT,ZT) = R2((CNTCT+10-SHNEG),X)
392 D(CNTCT,ZB) = (D(CNTCT,ZB) + R4((CNTCT+10-SHIFT),X))/2
394 R4((CNTCT+10-SHIFT),X) = D(CNTCT,ZB)
400 D(CNTCT,ZP) = D(CNTCT,ZP)/2

***** output section deleted *****

540 NEXT CNTCT
560 IF SW = 0 THEN SHIFT = SHIFT + 0:
   IF SHIFT >= 2 THEN SW = 1: GOTO 580
570 IF SW = 1 THEN SHIFT = SHIFT - 0:
   IF SHIFT <= -2 THEN SW = 0
580 IF SWZ = 0 THEN SHNEG = SHNEG + 0:
   IF SHNEG >= 2 THEN SWZ = 1: GOTO 610
590 IF SWZ = 1 THEN SHNEG = SHNEG - 0:
   IF SHNEG <= -2 THEN SWZ = 0
610 NEXT N
VIII. VITA

James Salacain was born in Commack, New York in 1961. After completing High School, he entered into the Photographic Technology Program at the State University of New York at Farmingdale. Upon graduating with honors and receiving his Associate of Science Degree, James entered the Photographic Science and Instrumentation program at The Rochester Institute of Technology where he is currently working towards a Bachelor of Science Degree. Upon graduating, James hopes to secure employment in the Opto-Electrical or Telecommunications field.