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Detection and control of a bichrome printing ribbon; a study in design

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DETECTION AND CONTROL OF A BICHROME PRINTING RIBBON

A STUDY IN DESIGN

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by

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ABSTRACT

A control circuit for sensing and positioning a two color print ribbon under a printhead was designed and built into a working feasibility model.

The control circuitry successfully provided the following signals for which it was designed:

1. Automatically position a black color ribbon section under the printhead during the initial mode.
2. Turn off the ribbon advance solenoid via photosensors after each new ribbon section advance.
3. Control the turn-off time so that when the ribbon stops a new color section is positioned under the printhead accurately and within tolerance.
4. Turn off the printer to prevent printing erroneous tags if the correct color is not sampled under the printhead before printing.

This control circuit concept and design will be used in the engineering model of the high speed color bar coded tag printer.

The printer will print merchandising tags containing both human readable characters and machine readable encoded color bars. The encoded color bars consist of black, green and white bars which can be read only by an electro-optic decoding device, not by visual inspection.

ACKNOWLEDGMENT

I wish to express my appreciation to the National Cash Register Company for making their facilities available to me for the research phase of this project. I would like to also thank Dr. James B. Y. Tsui for his guidance in my thesis work.

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I. INTRODUCTION

The objective of this thesis is to design the control circuitry for the color ribbon transport mechanism in a high speed tag printer. The tag printer prints color bar coded merchandising price tags similar to those shown in Figure 1, and used in the NCR Point-of-Sale System. There are two models under discussion here, the ribbon transport feasibility model and the tag printer engineering model. The following thesis work describes only the design of the feasibility model but the tag printer engineering model dictated the system specs and requirements.

To test and evaluate the control circuit design concepts with a minimum of cost and risk, a ribbon transport feasibility model was actually constructed and tested in the lab. This model automatically moves color ribbon sections under the printhead, monitors for correct ribbon color and position, and aborts the run if error conditions occur. The feasibility model demonstrated that the control circuit was valid and functional and therefore this concept can be used in the tag printer engineering model.

The design objective of the tag printer is to make it automatic and free of operator control in such

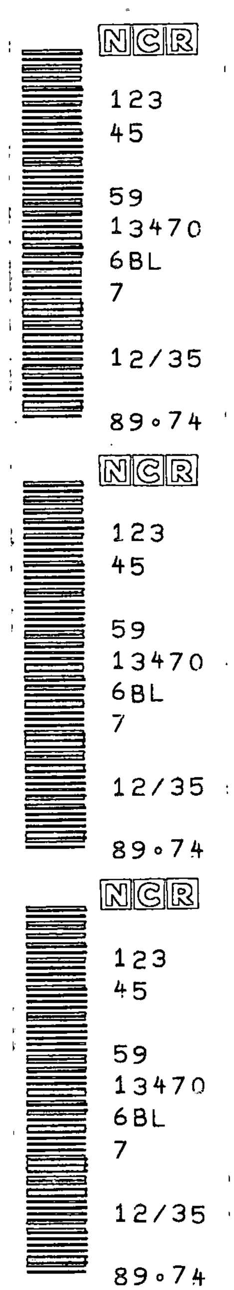


FIGURE 1. EXAMPLE OF A COLOR BAR PRINTED TAG

operations as ribbon alignment upon reel loading and in emitting erroneously printed tags. This is a complicated matter because the machine tag printing scheme is complex and sophisticated. The color ribbon is in alternating sections and the black section must be accurately aligned under the printhead when a new reel of ribbon is loaded or when a new print run of tags is started. Whenever misprinted tags occur due to ribbon misalignment, the machine will automatically cut them off and eject them as bad tags.

The two color ribbon consists of alternating green and black sections .400" long by 1.75" wide (See Figure 2.) which must be positioned under the printhead within tolerance. In the tag printer the color of the ribbon under the printhead has to be known each time before printing. At the time of circuit development the only two color printing ribbon which was available had color sections 2.00" long by 1.75" wide (See Figure 3.) and this was used in the feasibility model. Printing did not occur in the feasibility model because the objective at this stage was to demonstrate ribbon start and stop transport control.

In the tag printer engineering model the control circuitry must sample the color under the printhead and

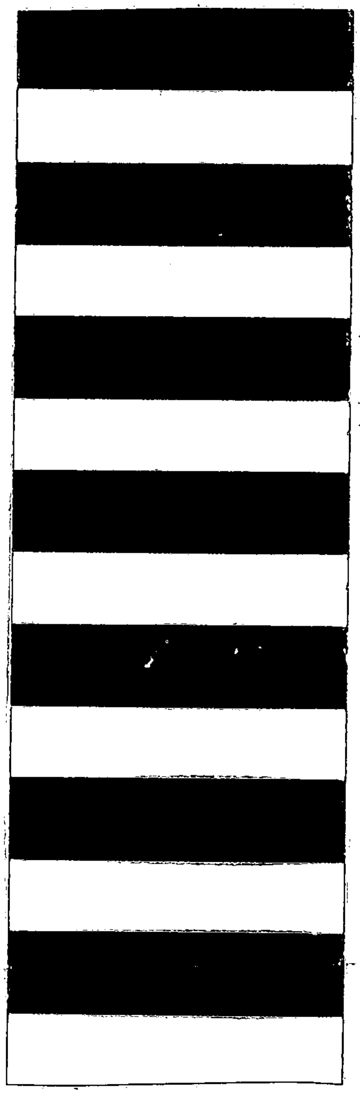


FIGURE 2. BLACK AND GREEN PRINT RIBBON, (.400"x1.75")

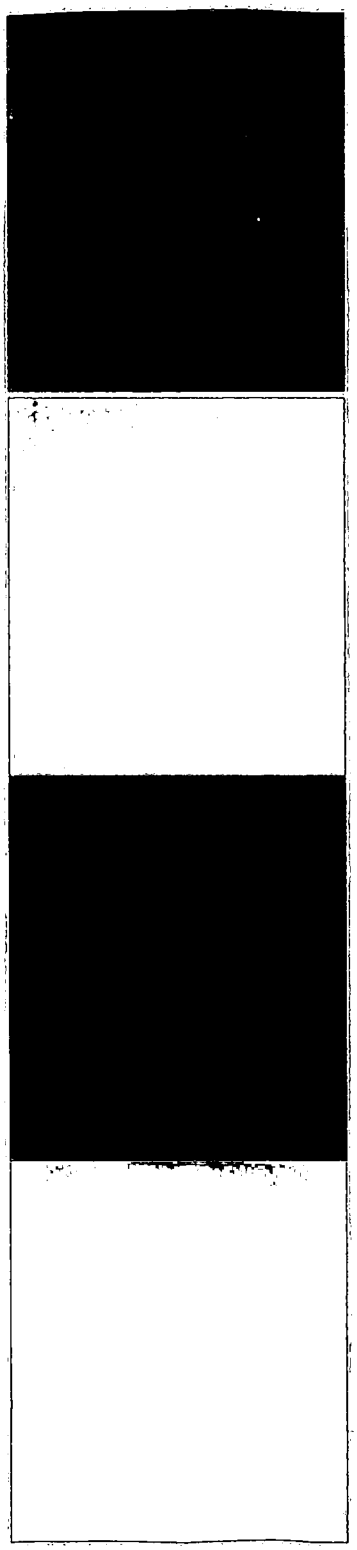


FIGURE 3. BLACK AND GREEN PRINT RIBBON (2.00"x1.75")

make a decision as to its correctness. If it is the correct color, the printhead will print bars of that particular color in the encoded area on the tag, then the next color section is advanced into position and this same procedure will continue.

If the incorrect color section is sampled under the printhead, the control circuitry must inhibit the bar printing, activate the tag cutoff knife to discontinue the tag run, and initiate machine shutdown proceedings to prevent any misprinted tags from coming out of the printer. A misprinted tag is one with the black and green bars reversed. This can be detected only by a color bar code electro-optical reader, never by an operator's visual inspection.

If the color sections are not centered under the printhead within a specified tolerance, the photosensors will detect this and send out an error signal to abort the run and stop the machine as mentioned above. When the printer is re-started again, this ribbon misalignment will automatically correct itself because the printer goes thru initialization modes as described in a later section.

II. TRANSPORT SYSTEM DEVELOPMENT

The engineering model of the tag printer must print 200 tags per minute or 3 1/3 tags per second. Hence the cycle time per printed tag is $\frac{60}{200}$ = 300 ms. per tag. During this 300 ms. the green and black bars must be printed on plain white tag stock. The color bars are printed in series by color. This means first all the bars to be encoded black are printed black, and then all the bars to be encoded green are printed green.

A DC solenoid activates the ribbon driving mechanism gears and pinch rolls upon the proper command from the control circuitry. Since the printer output is 200 tags per minute and two color sections per tag have to be advanced, the solenoid activation rep rate is 400 pulses per minute.

When the solenoid is energized the armature pulls in the mechanical load. This action engages the gears and pinch rolls and the ribbon starts moving at a velocity of 10 $\frac{\text{inch}}{\text{sec.}}$ or 10 $\frac{\text{mils}}{\text{ms.}}$. An integral number of color sections away from the printhead there are two phototransistors, A and B, which are located at a distance of less than one color section apart so that they will be inside one color section dimension. These phototransistors are used to determine the colors of the ribbon. As the color sections move past A and B, at one time they both will see like colors and thus initiate a turnoff pulse. Between the time the turnoff pulse is initiated and the solenoid plunger is pulled out of the core, the ribbon is still traveling at a rate of 10 $\frac{\text{mils}}{\text{ms.}}$. Since we can allow only about 30 to 40 mils of ribbon in wasting due to delay of turnoff, the dropout time of the solenoid is constrained at 3 or 4 milliseconds.

To avoid any positioning errors from accumulating over a large print run, the ribbon transport control mechanism was designed to isolate the start ribbon movement from the stop ribbon movement so that they are independent of each other. This was done by having a rotating cam trip a switch to start the ribbon drive mechanism. Once the ribbon starts moving, the photosensors will be used to turn off the drive by sensing a transition from unlike to like colors. After a new color section is advanced into position, the sensors, via digital logic, must determine whether the correct color is under the head for that particular machine phase and also whether the color is positioned within tolerance. If it is the incorrect color or out of positional tolerance, this is an error condition and the control circuitry then must initiate printer shutdown proceedings. When these tags come out of the printer they will be visually recognized as misprinted because there will be no color bars printed on them.

The main camshaft in the machine is used for timing as well as ribbon driving. One camshaft revolution will result in one completely printed tag. In the first camshaft revolution no color bar printing occurs because a new tag is positioned under the printhead. During the first camshaft revolution, (300 ms.) the control circuit must go thru the initialization mode. That means it must keep automatically advancing ribbon sections until a black section is under the printhead. The worst case condition would be two complete sections moved. This is all automatic and thus any manual alignment of the ribbon by the operator is eliminated. The only time the photosensors initiate both a ribbon move pulse as well as the turn-off pulse is at the loading and start of each new reel of ribbon. During the remaining printing run duration, the photosensor circuit will monitor the colors and provide the turn-off pulse at the appropriate time. If the ribbon color sections are out of step with the machine timing phase or out of positional tolerance under the print-head, an error signal will be sent to activate the abort circuit as mentioned above.

A. FEASIBILITY MODEL CONSTRAINTS

The final engineering model of the printer will have numerous cam activated switches for gating the electronic control circuitry in synchronization with the main camshaft. There will also be mechanical sensing switches which will sense the presence of a tag in the print station sequence in order to gate the control circuitry.

The ribbon transport feasibility model was built with only two cam activated switches and two toggle switches in order to test the ribbon transport design concepts, but still keep the hardware implementation simple and less costly. The toggle switches simulate the mechanical sensing switches to control the two printer modes of RUN or INITIALIZATION MODE. The two cams are the SAMPLING CAM and the MOVE RIBBON CAM.

When the feasibility model was designed the required ribbon shown in Figure 2 with .400 inch long by 1.75 inch wide black and green color sections was not available. It was decided to use the ribbon shown in Figure 3 because it was the only one available. This ribbon had color sections 2.00 inches long by 1.75 inches wide and therefore because of the 1.600

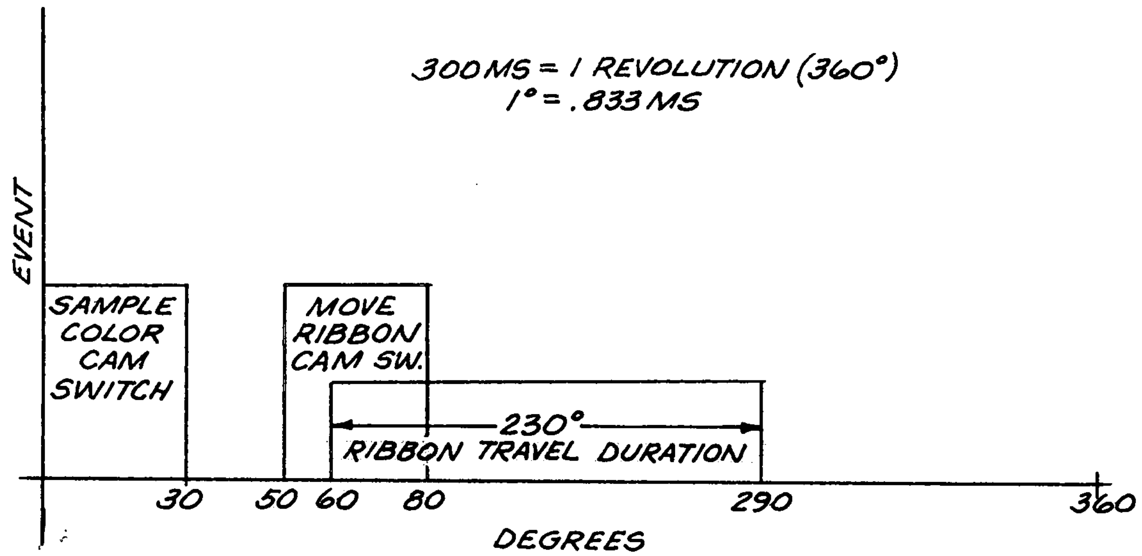


FIGURE 4. EVENT TIMING DIAGRAM

inches of longer ribbon length the ribbon advance timing had to be modified. The required ribbon advance velocity of 10 $\frac{\text{mils}}{\text{ms.}}$ could still be tested, but in the machine period of one revolution (300 ms.), only one two inch section could be advanced since the elapsed time would be 200 ms. out of the total 300 ms. period. (See Figure 4.)

B. CONTROL CIRCUIT SYSTEM DESIGN PHILOSOPHY

In this section the overall control circuit design philosophy will be introduced and briefly explained. A thorough analysis and understanding should not be attempted at this time because in the next section a detailed explanation of each mode and circuit will follow.

The control system consists basically of the decision logic block and a solenoid power switching circuit as shown in Figure 5. The input signals to the logic consist of error signals from the photodetectors, gating signals from the cam activated switches, and mode signals from the front panel toggle switches. The decision logic output signal either activates the solenoid or aborts the run, depending on the machine operating mode; see Figure 6. The two basic operating modes are the INITIALIZATION MODE and the RUN MODE. In the INITIALIZATION MODE the photodetectors perform two tasks; they must initiate both the ribbon advance pulse and the turnoff pulse. In the RUN MODE the photodetectors give only the turnoff pulse while a cam switch gives the ribbon advance command. While also in the RUN MODE the photodetectors activate the abort circuit if they sense error conditions (this

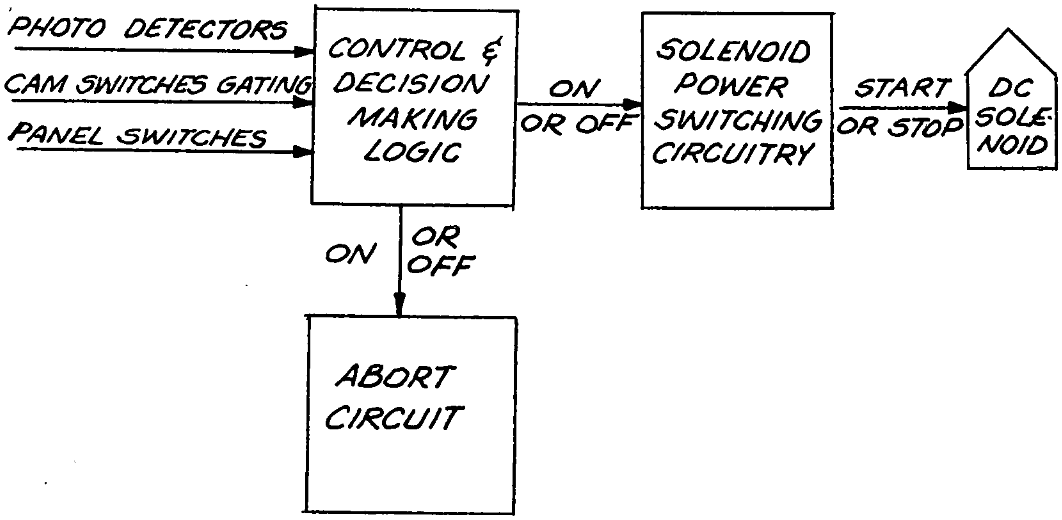


FIGURE 5. SYSTEM BLOCK DIAGRAM

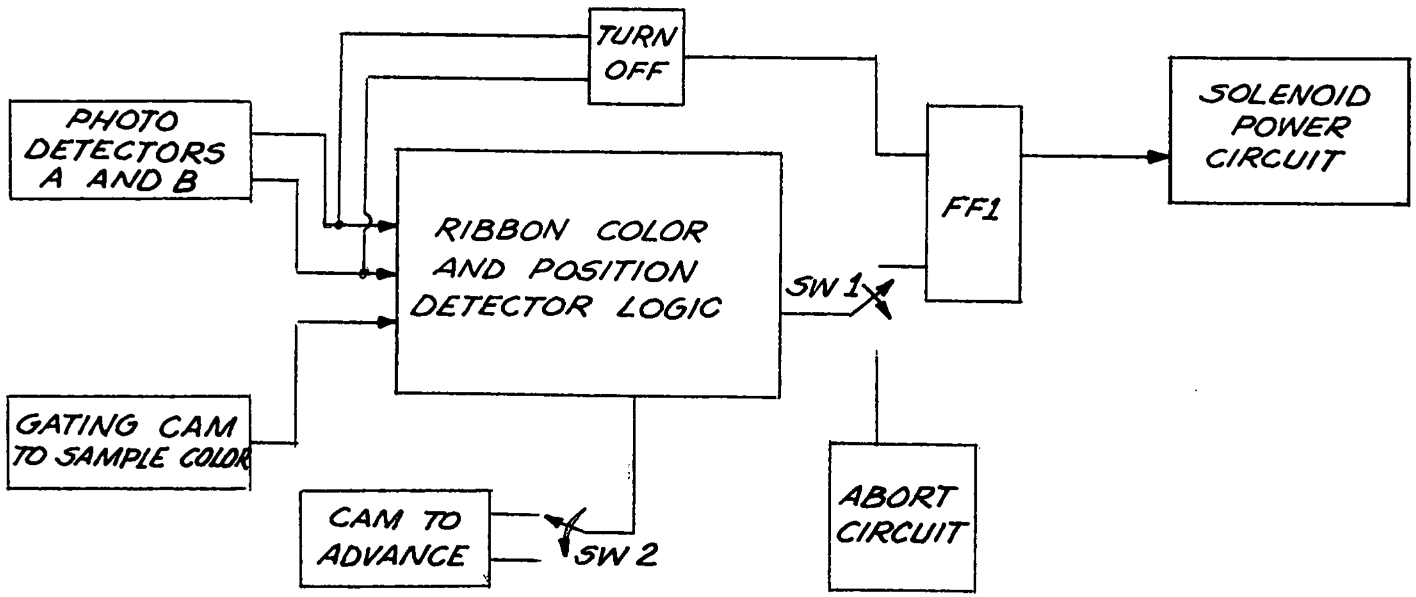
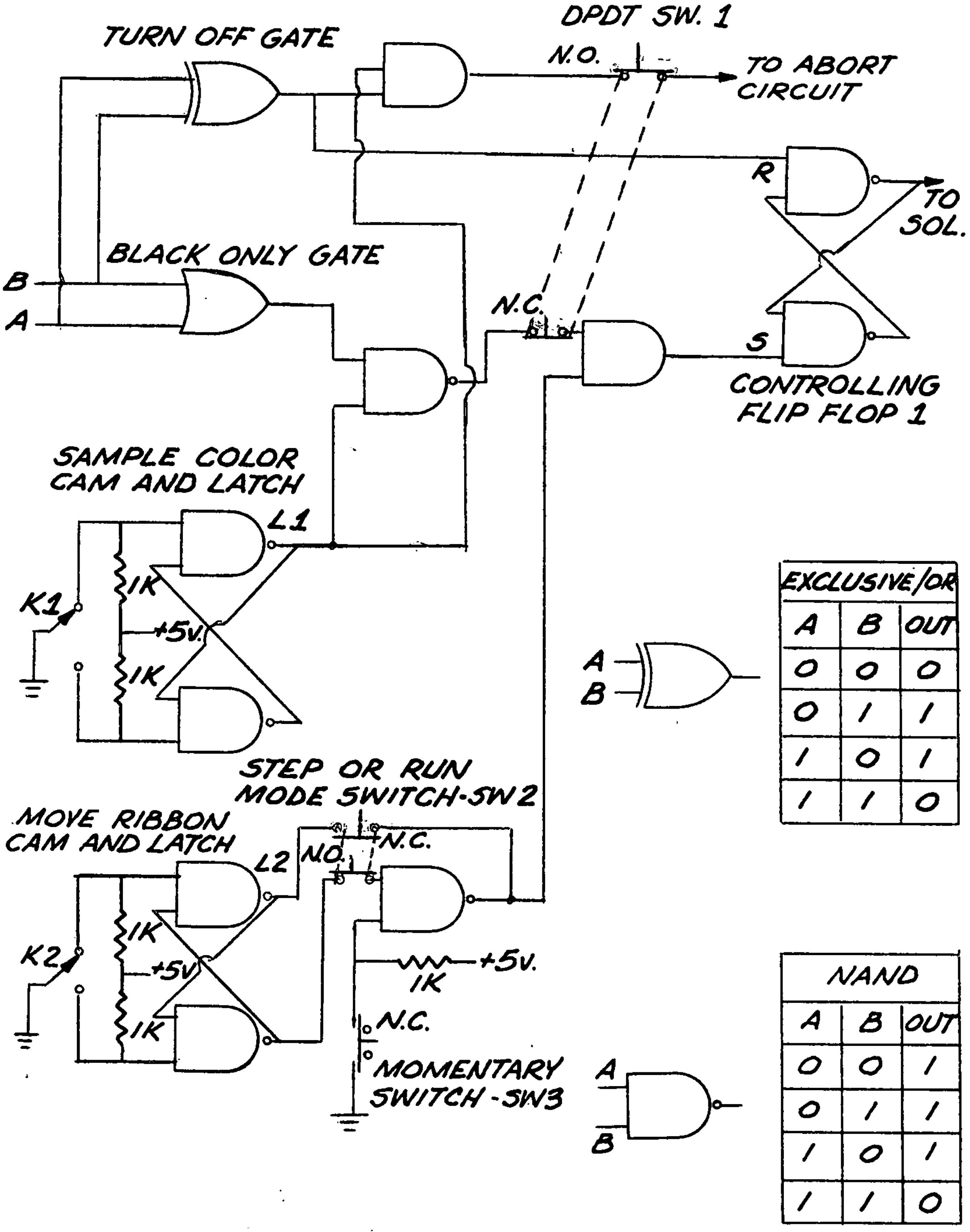


FIGURE 6. SYSTEM FUNCTIONAL BLOCK DIAGRAM

will be defined later).

The initialization mode occurs at the start of every cycle. One cycle is one machine shaft revolution during which one ribbon color section is advanced. If the wrong color is under photodetectors A and B while the machine is in the initialization mode, then an error signal occurs and is sequenced through the logic gates to FF1. (See Figure 6.) This error signal sets FF1 which in turn activates the transport solenoid to advance the ribbon.

Panel switch #1 determines INITIALIZATION MODE or RUN MODE (see Figure 7). In the RUN MODE the N.O. contacts of SW1 are closed and photodetector error signals are channeled to the abort circuit.



EXCLUSIVE/OR		
A	B	OUT
0	0	0
0	1	1
1	0	1
1	1	0

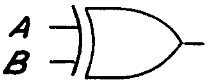
NAND		
A	B	OUT
0	0	1
0	1	1
1	0	1
1	1	0

FIGURE 7. DECISION LOGIC SCHEMATIC

C. INITIALIZATION MODE CIRCUIT

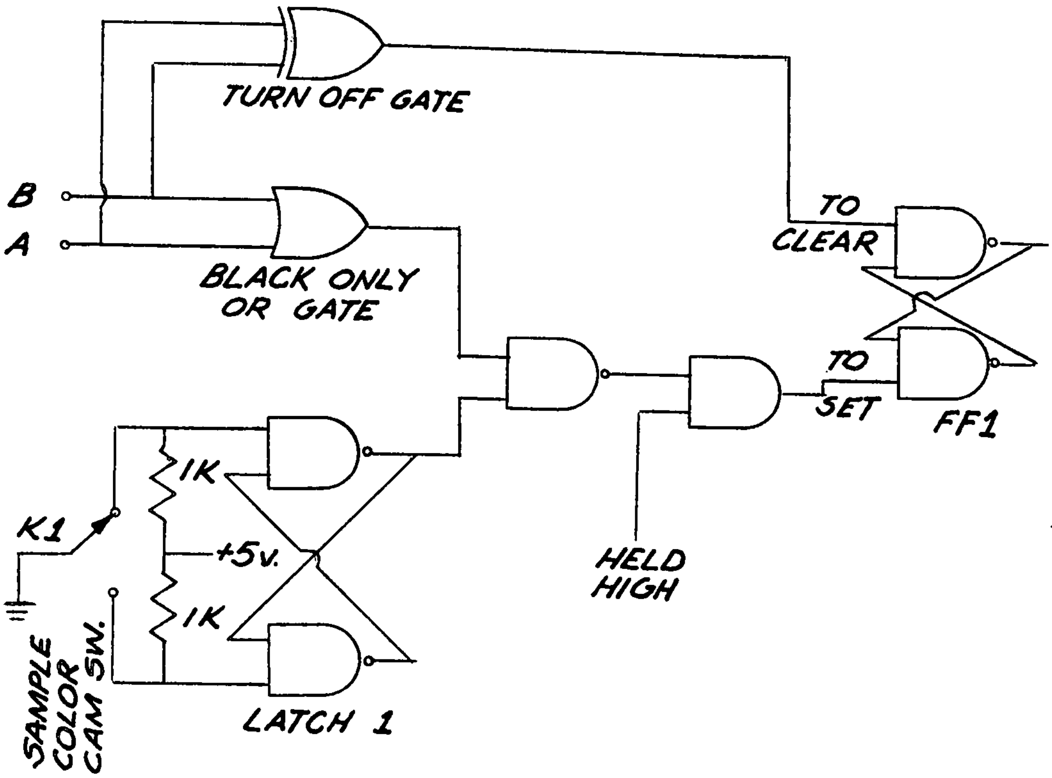
In the initialization mode the objective is to automatically advance and align a black ribbon section under the printhead. This is accomplished in the following way (see Figure 8). Cam switch K1 and latch L1 provide a gating signal which tells when to sample the output of the "Black Only" OR Gate. The inputs to the OR gate come right from the photodetectors and are defined as Black = 0, Green = 1. Looking at the OR truth table in Figure 8 it can be seen that any combination of A and B except A = Black (0) and B = Black (0) will give a 1 output. A "1" output is defined as an error signal. When the Sample Color Cam K1 gives a gating signal, the output of latch L1, which eliminates contact bounce effects from the cam actuated switch, is high (1). This high is NANDED with the error signal which is also high to give a low output into the next gate which is an AND gate. During this time one side of that AND gate is held high and since the other input is low, the AND output is low. This low sets FF1, and FF1 in turn energizes the solenoid to advance ribbon.

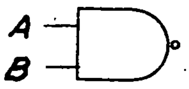
Turn-off is accomplished by the EXCLUSIVE-OR gate. Looking at its truth table in Figure 8, when the inputs are alike this means the photodetectors see a solid



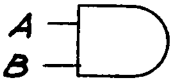
EXCLUSIVE/OR		
A	B	OUT
0	0	0
0	1	1
1	0	1
1	1	0

OR		
A	B	OUT
0	0	0
0	1	1
1	0	1
1	1	1





NAND		
A	B	OUT
0	0	1
0	1	1
1	0	1
1	1	0



AND		
A	B	OUT
0	0	0
0	1	0
1	0	0
1	1	1

FIGURE 8. INITIALIZATION MODE CIRCUIT

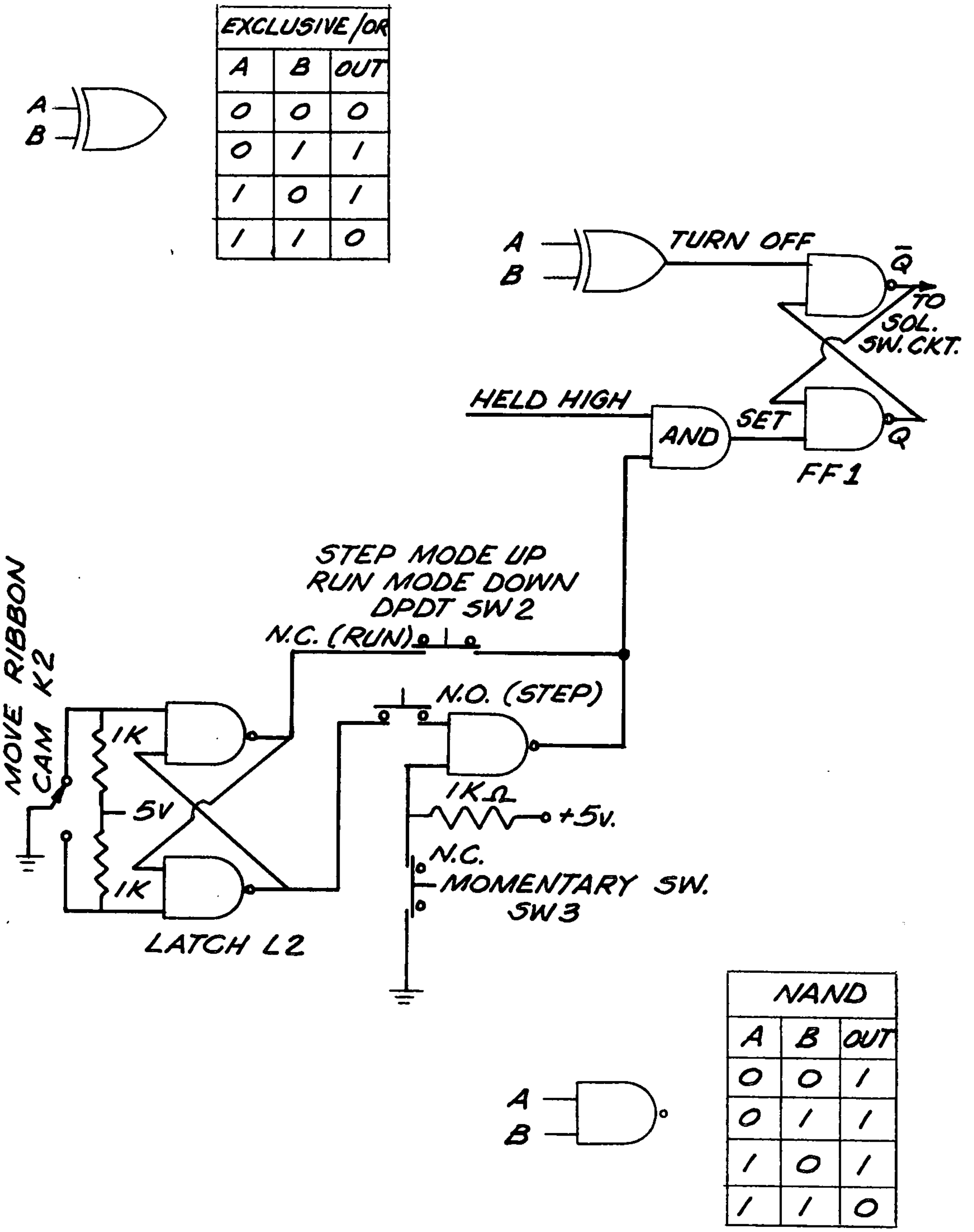
color (it doesn't matter whether it is green or black at this point; the reason why will be explained later.) This causes the output of the EXCLUSIVE-OR to become low which in turn clears FF1. Thus, the solenoid will be de-energized and the ribbon will stop in position under the printhead. On the next SAMPLE CAM cycle the photosensors will look at the ribbon color again and if it is green then another error signal (high) will come out of the "Black Only" OR gate and will be sequenced as mentioned previously to move the next ribbon section into position, which this time will be black.

The basic design concept of turn-off and color detection by using phototransistors and logic gates was successfully proven feasible with this circuit.

D. RUN MODE-STEP MODE CIRCUIT

After going through the initialization mode and having made the necessary ribbon advance steps, the transport mechanism comes to rest with A = black (0) and B = black (0). This means there is a complete black section of color ribbon accurately positioned under the printhead and ready for printing the first color, which is black. At this point the machine mode must be changed from the INITIALIZATION MODE to the RUN MODE. The feasibility test model implements this function with two DPDT toggle switches SW 1 and SW 2, illustrated in Figure 7. In the RUN MODE the N.C. contacts of SW 1 removes the initialization signal path from the AND gate leading to FF 1 and at the same time the N.O. contacts of SW 1 are closed and connect the abort signal channel to the abort circuit. This is defined as the normal mode of operation. Also while in the RUN MODE the N.C. contacts of SW 2 connect the MOVE RIBBON CAM CHANNEL of cam K_2 and latch L_2 to the SET input terminal of FF 1 through the previously mentioned AND gate.

In the RUN MODE, a mechanical cam K_2 will originate the signal to energize the solenoid and start ribbon moving (see Figure 9). In the INITIALIZATION



EXCLUSIVE/OR		
A	B	OUT
0	0	0
0	1	1
1	0	1
1	1	0

NAND		
A	B	OUT
0	0	1
0	1	1
1	0	1
1	1	0

FIGURE 9. STEP MODE - RUN MODE CIRCUIT

MODE previously described, the photosensors did this job. In the RUN MODE the photosensors will act merely as the shut-off gates when they see the correct ribbon color transition. The cam switch K_2 sets the FF 1 and it in turn energizes the solenoid power switching circuit to start the ribbon moving (see Figure 9). The FF 1 is latched in the set state until reset by the EXCLUSIVE-OR which acts as the TURN-OFF gate. The output of the EXCLUSIVE-OR TURN-OFF gate is controlled by photosensors A and B seeing the color transition from unlike colors to like colors. Shown in the truth table of Figure 9, when the inputs to an EXCLUSIVE-OR gate are alike, the output is zero, which resets FF 1. FF 1 in turn will switch off the solenoid and thus stop the ribbon move mechanism.

To test the repeatability of stopping the color sections accurately under the printhead while in the RUN MODE, a STEP MODE provision was designed. The color ribbon sections are advancing at the continuous rate of 3 1/3 $\frac{\text{sections}}{\text{second}}$ in the run mode, and pause under the printhead for 15 ms. as they would under actual printing conditions. This rate is much too fast to allow any visual inspection and measurement of positioning accuracy. Therefore, SW 2 and SW 3 was designed to further control the RUN MODE to a STEP MODE (see Figure 9). While in the RUN MODE, the N.C. contacts of SW 2 are closed and channel the ribbon advance signal from K_2 and latch L_2 into FF 1 through an AND gate. In the STEP MODE, the N.C. contacts are broken and the N.O. contacts are made so that the cam switched signal from K_2 and L_2 in conjunction with momentary pushbutton SW 3 is NANDED and commands the ribbon to be moved by NANDING these 2 signals (see Figure 9) and then introducing the output to SET of FF 1 through an AND gate.

Thus in the STEP MODE, after ribbon is advanced, the ribbon pauses in position under the printhead indefinitely until SW 3 is opened. One must be cautioned here that if SW 3 is held open continuously, the MOVE RIBBON CAM signal will advance ribbon continuously; therefore, it must be a momentary operation. While the ribbon is in position indefinitely, the positioning accuracy measurements can be made.

E. ABORT RUN CIRCUIT

Since there are no printing provisions in the feasibility model, it is not necessary to know which color is directly under the head. It is necessary, however, only to know that there is a solid color under the head. The function of the abort circuit is to sample the color section under the head just before print, and to abort the printing if error conditions occur.

In the feasibility model this was accomplished by ANDING together the output of the TURN-OFF EXCLUSIVE-OR gate and the sample cam latch L1. The output of this AND gate turns on the abort circuit by energizing relay R1 (See Figure 10). In the engineering model this abort signal is very important because it initiates machine turn-off procedures, activates a knife solenoid to cut off the misprinted tags, and inhibits any further color bar printing until the color sections' synchronization is corrected.

Besides just checking for proper color conditions such as A=black, B=black, or A=green, B=green, the abort circuit must also tell that the color section stopped and was positioned accurately under the printhead. By physically locating the photosensors beneath the ribbon at the printstation so that the relative distance between them is 1.750 inches we can detect the positioning accuracy in stopping of the ribbon color sections.

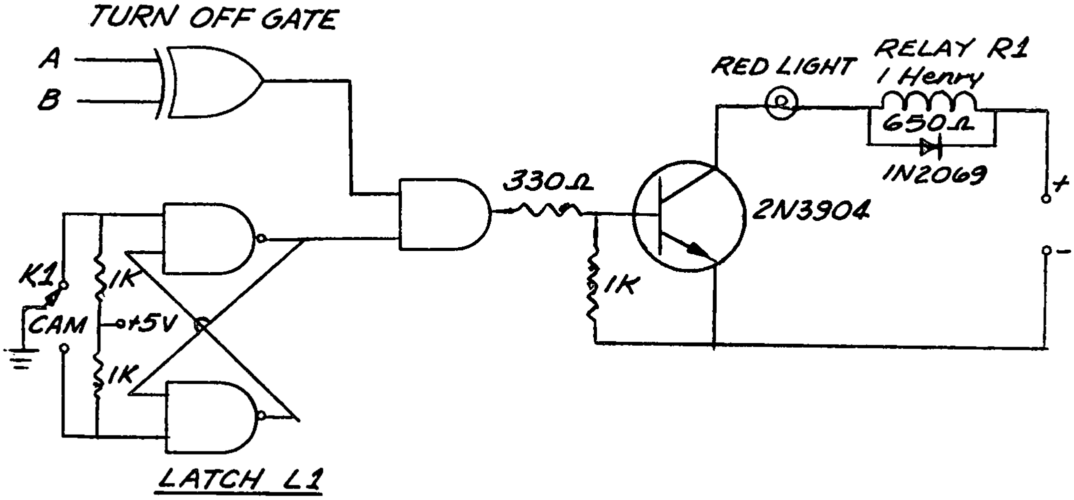


FIGURE 10. ABORT RUN CIRCUIT

F. SOLENOID DRIVER POWER SWITCHING CIRCUIT

This circuit was designed by the combined use of classical and experimental methods. Logic level signals into Q_1 will switch Q_3 and thus energize the B-21 solenoid coil in the following way. (See Figure 11.) When the logic input signal into Q_1 is high, Q_1 will switch on and thus switch on Q_2, which will charge up capacitor C_1, with Q_3 off. In this mode the solenoid is not energized and the capacitor C_1 is charging via Q_2 and R_5. When the logic input signal is low, Q_1 goes off, Q_2 goes off, and Q_3 goes on. This action discharges C_1 thru the coil winding and thus energizes the solenoid. After the solenoid is energized, it is held in by the holding current provided thru the 20K ohm R_9 from the power supply. When the logic input signal into Q_1 is high again, Q_3 goes off de-energizing the B-21 solenoid, Q_1 and Q_2 turn on, and the cycle is repeated.

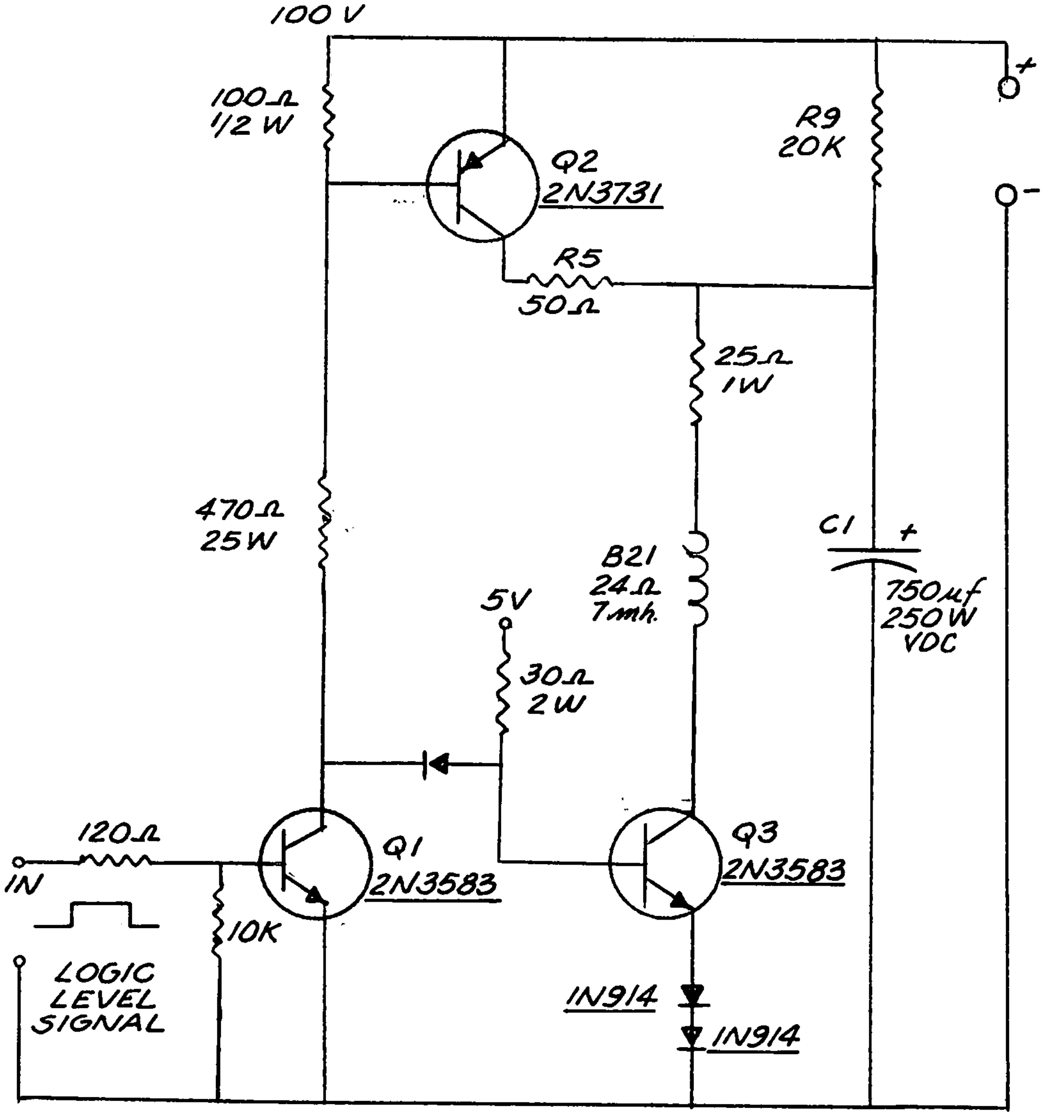


FIGURE 11. SOLENOID DRIVER CIRCUIT

III. CONCLUSIONS

When the control circuit was connected to the transport mechanism, the following results were noted:

1. The control logic and the switching power circuit performed as designed and per calculations.
2. The ribbon transport control concept and principles are valid and will be incorporated in future models of the tag printer.
3. The mechanical load for the solenoid was too large when working in the dynamic or "RUN" mode.
4. The solenoid dropout time exceeds the maximum 3 ms allowed by the mechanism.
5. A third photosensor should be added to provide more advance warning of the turn-off signal and thus compensate for the delay due to inertia.
6. Further experiments should be carried out to replace the solenoid pullout spring with possibly another solenoid working in the pull-out mode.

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