LEXMARK ROTOARY SHAFT ENCODER

[SYSTEM DESIGN SPECIFICATIONS]

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1.0 System Description

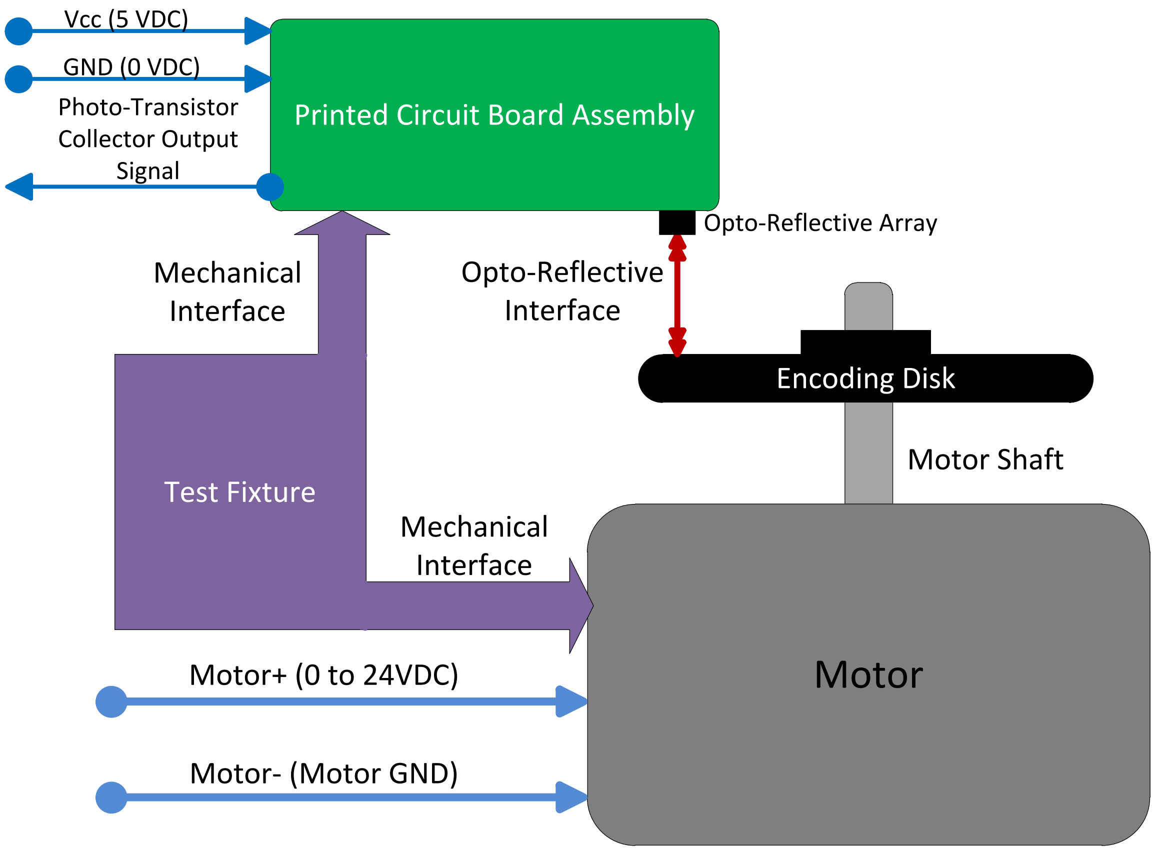

Figure 1: System Block Diagram

Developed	Test Fixture	Encoding Disk	Printed Circuit Board Assembly
Provided by Lexmark	Motor	Encoding Disk	
COTS	Opto-Reflective Array		

Figure 2: Legend of Origin

The two figures above show our system as it will be during our testing procedures, which shall be reviewed in detail later in this document. The test fixture, some of our encoding disks, and our printed circuit board assembly were all developed by our team to fit the requirements of this project. We were also provided the rest of our encoding disks and the motors to be used by Lexmark. The only major component which we acquired ourselves was the opto-reflective array.

The overall goal of this project is to reduce the cost of implementing a new design of shaft encoders to be used in Lexmark's printers. Our thought process led us to believe that if we could keep the cost of the encoding disk the same as the current production disk, while reducing the cost of the opto-reflective array, we could reduce the overall encoder cost. We chose the three opto-reflective arrays based on the following criteria. We wanted an array that was planar, meaning the LED and photo transistor are side by side in the package. We also wanted an array without any additional electrical components, meaning no electronics which are not currently in Lexmark's opto-transmissive encoder. These choices were due to our derived requirement from the System Requirement Specifications stating that the spacing between the encoding disk and opto-reflective array needs to be carefully controlled. We discovered there are array packages more advanced than a simple IR led and IR phototransistor; however, cost is also a requirement for this project so we had to make sure we were finding a solution that had the best chance of reducing the cost from Lexmark's current design.

1.1 System Interfaces

1.1.1 Electrical Interface

DC power will be applied to the custom-made PCB via the JST B5B-PH-K-S 5-pin connector assembly. The custom-made PCB will receive input voltages of 24 Volts to power the Grape 2 3056582-004 motor, 5.0 or 3.3 Volts, and also have a ground connected all via the 5-pin connector. The output signal will also be sent out via that same assembly. The signal needs to meet certain requirements. The output should be a single channel 3.3 Volt level signal that will be passed through a Schmitt Trigger. Once the signal is passed through the Schmitt trigger, the input high must be ≥ 2.2 Volts, the input low must be ≤ 0.6 Volts, and the minimum On-Time and Off-Time must be greater than 17 microseconds each.

1) <u>JST B5B-PH-K-S 5-Pin Connector</u>

The JST B5B-PH-K-S five pin connector that we will be using will be attached directly to our custom-made PCB, which is attached to the Grape 2 3056582-004 motor assembly. A picture of the actual JST B5B-PH-K-S connector can be seen in Figure 3. As seen in Figure 4, the pin-out for the JST B5B-PH-K-S connector is as follows:

1) Pin 1: Input to IR array (power supply for LED and phototransistor)
2) Pin 2: Feedback/output of IR sensor
3) Pin 3: Ground connection
4) Pin 4: Negative motor lead (ground for testing)
5) Pin 5: Positive motor lead

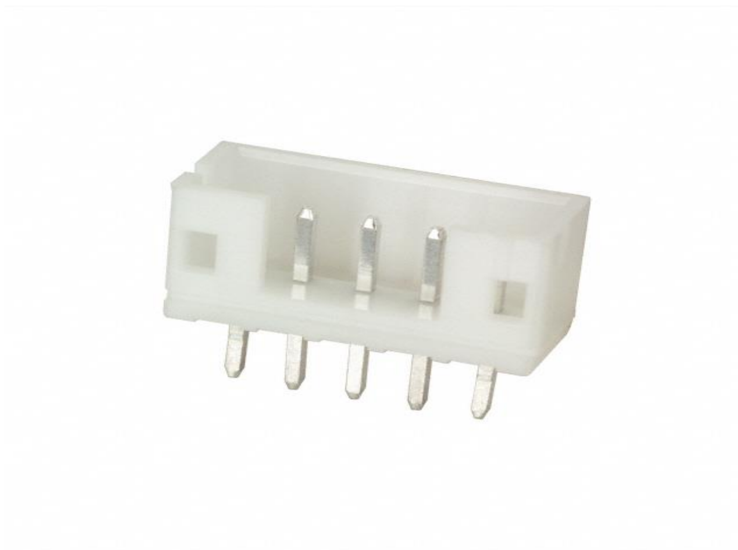

Figure 3: 5-pin connector JST B5B-PH-K-S

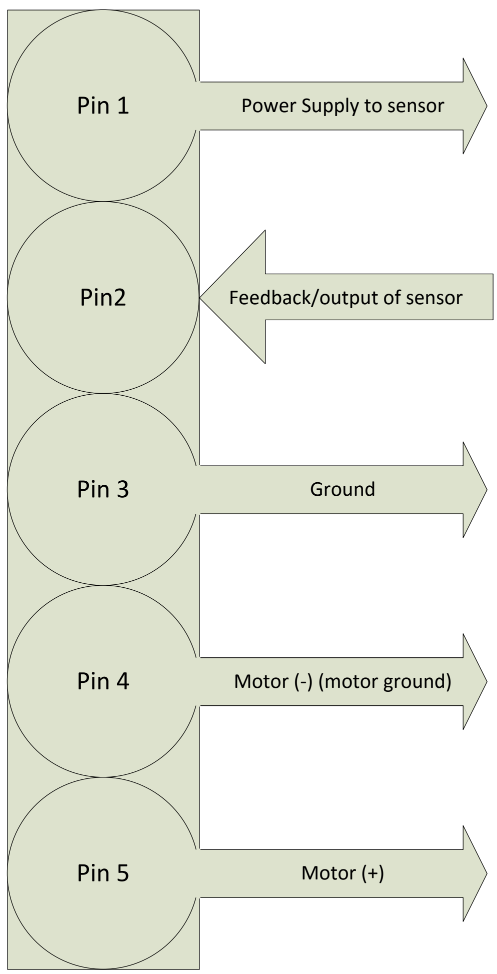

Figure 4: 5-Pin Connector Pin-Out for B5B-PH-K-S

1.1.2 Mechanical Interface

1) JST B5B-PH-K-S 5-Pin Connector

The JST B5B-PH-K-S five pin connector will be used to physically connect the Grape 2 3056582-004 motor to the external circuitry used by the printer. Note that the Schmitt trigger or other signal processing circuitry is not on the custom-made PCB we are designing and is kept off board somewhere else in the printer.

2) Custom-Made Test Fixture

The mechanical engineer majors in our team have created a custom-made test fixture to anchor the Grape 2 3056582-004 motor during our testing procedures. This will ensure that the signal we read from the Opto-Reflective Array is reliable, reproducible and free from errors. The previous student team to work on this project did not have a steady test fixture and used their hands to secure the motor during testing. We feel that using a custom test fixture will not only help with the accuracy and precision of our testing, but will also enable us to test the spacing requirement precisely.

Our test fixture consists of a set of Cen-Tech Model 47256 calipers, which can measure to 0.03mm +/- 0.01mm. The Cen-Tech Model 47256 calipers are securely attached to the test fixture by screws and also have our custom-made PCB attached to them by screws so that we can accurately adjust and test the array-to-encoding disk spacing as required. The motor is also firmly attached to the test fixture, such that the encoding disk and Opto-Reflective Array are in parallel planes. Our custom-made test fixture can be seen below in figure 5.

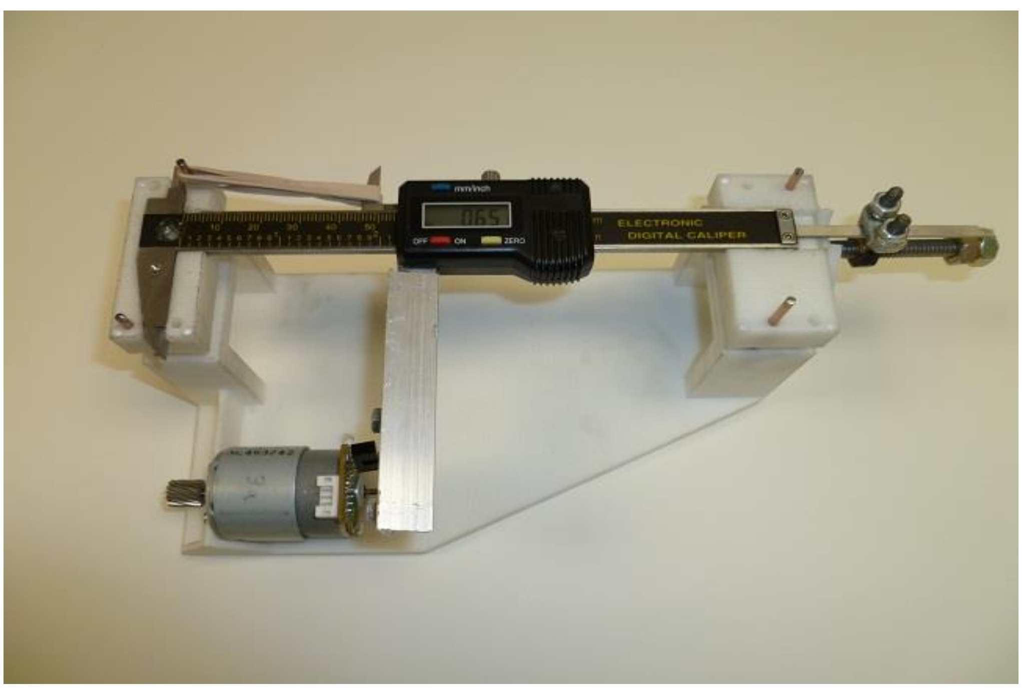

Figure 5: Custom-Made Test Fixture

1.2 Major Components

1.2.1 Motor

The motor provided to us by Lexmark is the Grape2 3056582-004. We were given three to be used in our testing. The motor itself will be left unchanged. We will be replacing the current PCB with one that we have developed. We will also be removing the transmissive encoding disk and replace it with the reflective disks we have created for the testing procedures.

The motor is required to run at a maximum speed of 6000 +/- 150 RPM, and at a minimum of 200 RPM. It will be physically connected to the test fixture via the same screws that are used to mount the motor in Lexmark's printers. Our custom-made PCB is directly mounted to the Grape2 3056582-004 motor in the same location as the current PCB being used by Lexmark. Electrical power and ground will be supplied to the motor via the circuit board, which will have on it the JST B5B-PH-K-S 5-pin connector. Positive DC voltage will be provided through pin 5. A ground connection, or a negative VDC connection, depending upon which test we or Lexmark run, will be provided through pin 4.

1.2.2 Encoding Disk

The encoding disk is physically attached to the shaft of the Grape2 3056582-004 motor. This allows the disk to spin at the same speed as the motor shaft, which will be necessary to calculate the RPM. There is also an optical connection between the opto-reflective array and the encoding disk. The spacing between these two components will be critical to our test proceedings.

1.2.3 Printed Circuit Board Assembly

We designed and fabricated our own PCBs using the facilities on UofL's campus. This allows us to implement our custom circuit design while maintaining the ability to use the various opto-reflective arrays we will be testing.

Our custom-made PCB will be mounted to the motor in the same fashion as the current PCB. Figure 3 shows the JST B5B-PH-K-S 5-pin connector. Figure 4 shows a pin out diagram.

Pin 1 provides either a 5 VDC or 3.3 VDC supply to the LED portion of the opto-reflective sensor array. This will provide power to the package and enable the LED to emit an IR beam to be reflected off of the encoding disk.

Pin 2 is the collector pulse train output from the photo transistor of the opto-reflective array. This signal will provide us with frequency measurements, which we can then use to calculate motor RPM. In Lexmark's printers, this signal will be sent to other circuitry and passed through a Schmitt trigger to process the signal so that accurate measurements are made during operation. For the purposes of our testing, we are not required to implement the Schmitt trigger or signal processing; however, we have one available to allow us to view the signal in both its processed and unprocessed forms.

Pin 3 is the ground for the PCB assembly.

Pin 4 can be used in multiple ways. For testing purposes, this pin can be tied to ground to provide the ground connection necessary to reference the positive voltage input to pin 5. Depending on what test is being run, pin 4 can also be used as a negative DC voltage input. Supplying a negative voltage simply causes the motor to spin in the opposite direction. If you view the encoding disk from the pinion end, a positive voltage applied will cause the shaft and encoding disk to rotate in a clockwise direction. By reversing the polarity, you can reverse the direction of rotation. The difference between the positive/negative voltages connections determine how fast the motor will spin. This allows us to vary the RPM speed from the required range of 200 up to 6000 +/- 150 RPM.

Pin 5 will provide positive DC voltage to the motor itself.

2.0 Detailed Design

The following section will give detailed descriptions of each major component and how they are implemented.

2.1 Printed Circuit Board Assembly

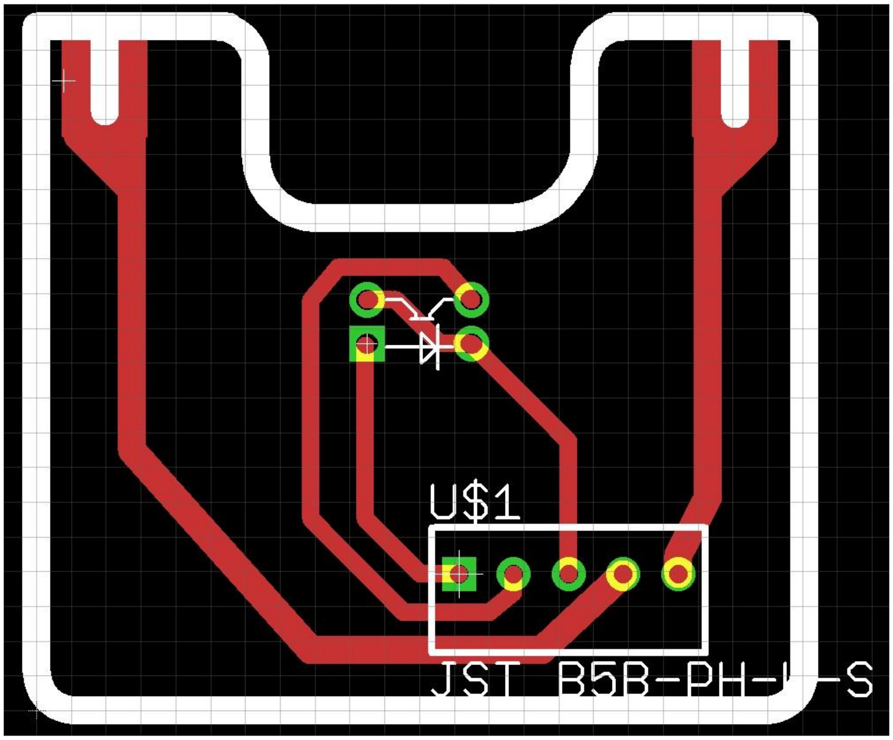

Figure 6: Eagle Layout of PCB Assembly

The figure above is a layout of our custom-made PCB using the software program Eagle. The following figure is a schematic of the circuitry to be used in the testing procedures.

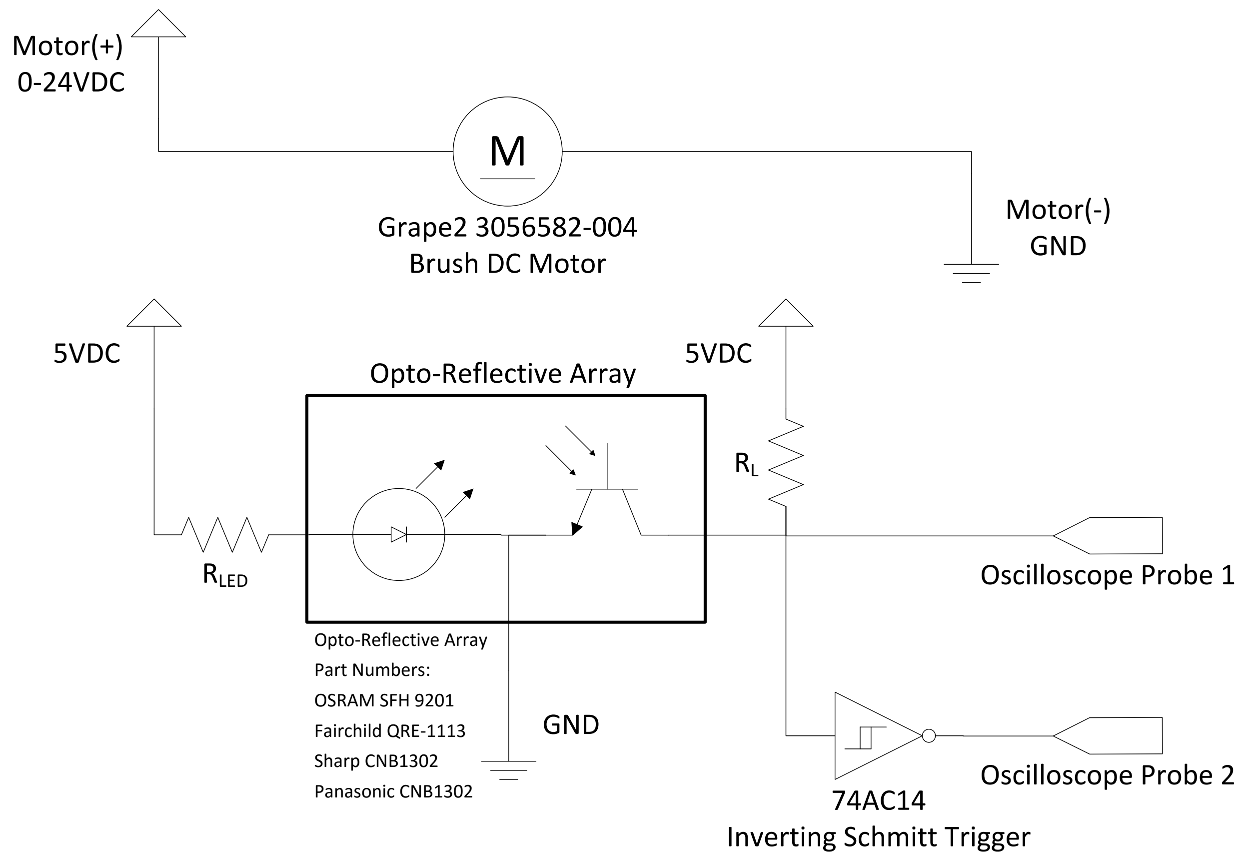

Figure 7: Testing Schematic

We will be using three different opto-reflective arrays during our testing. Each one will be placed on the PCB individually and tested to determine which is optimal. Note that the Inverting Schmitt Trigger is not required by Lexmark and is not located on our PCB Assembly.

The two resistors shown on this schematic are the LED Resistor (R_{LED}) and the Load Resistor (R_L). The load resistor was originally chosen to remain constant at 10 kΩ nominal (9.83 kΩ measured) for all sensors we will be testing. However, after preliminary testing it became apparent that R_L could be altered to improve the output signal based on the reflectivity of the encoder disk material. Nominal values used for R_L where 10 kΩ, 15 kΩ and 33 kΩ.

R_{LED} was chosen to maintain a constant forward current of 20mA through the IR LEDs of all the opto-reflective arrays. By maintaining a constant 5 VDC power supply and measuring the voltage drop across the LEDs we were able to select a R_{LED} which maintained 20mA +/- 0.1 mA for all the arrays. R_{LED} was held by a potentiometer at 189 Ω during all 5VDC power supply tests and was adjusted down to 104 Ω for all 3.3VDC power supply tests.

2.2 Encoding Disk

Lexmark provided several duplicates of the original black nylon encoding disk 18B1192. We have also been provided an aluminum version of that disk as well. Both of these have a 64 window designs. Lexmark has asked us to provide data using an eight window design, and a 48 or greater window design. Since the provided encoding disks have a 64 window pattern, we will be testing a 8, 48, and 64 window designs.

Using the 18B1192 as a platform, we were able to make several other disks. The first and simplest was spraying a hi-gloss white paint to coat the disk in order to see if simply changing the color would affect the reflectivity and effectiveness of our design. We also used the disk to sputter various elements. We attempted to sputter Aluminum and Chromium; however, they did not adhere well to the surface. Gold was later used and it adhered very well. The gold sputtered version will be used in testing to give us more data; however, we understand that due to its effect on the cost it will most likely not be used by Lexmark.

Using the facilities on the University of Louisville's campus, we were able to design and create a patterned disk out of a copper clad PCB material. We were able to fabricate 8, 16, 32, 48, and 64 window designs. The PCB disks were them simply laminated to the 18B1192 black nylon disks to allow them to be attached securely and simply to the motor shaft.

Finally, we also took the various patterns and printed them on semi-gloss photo paper in order to laminate them on to the 18B1192 black nylon disk. We did this to duplicate and expand upon the test results from the previous student team.

2.3 Motor

Lexmark has provided us with several Grape2 3056582-004 motors. These are brushed DC motors, which are currently being used in Lexmark's printers. We had no need to go and buy and/or design a motor ourselves because of this. Lexmark wanted to ensure any design improvements we came up with could be implemented using the current motor hardware.

3.0 Principles of Operation

3.1 Major Components

3.1.1 Printed Circuit Board (PCB) Assembly

The custom-made PCB is solder mounted onto the Grape 2 3056582-004 motor assembly. It consists of printed circuit traces, supporting circuit components, the opto-reflective array, and the JST B5B-PH-K-S 5-pin connector. The custom-made PCB receives DC power to it via the JST B5B-PH-K-S 5-pin connector. 24 Volts are applied to power the Grape 2 3056582-004 motor assembly and 5.0 or 3.3 Volts are applied to power the opto-reflective array. Once all are powered and running, the opto-reflective array sends a beam of light via the IR LED and is reflected off the encoding disk. This signal is sent off the custom-made PCB to an off-board Schmitt Trigger. The input high must be ≥ 2.2 Volts, the input low must be ≤ 0.6 Volts, and the minimum On-Time and Off-Time must be greater than 17 microseconds each.

3.1.2 Opto-Reflective Array

The opto-reflective array will be supplied with either 5.0 Volts or 3.3 Volts to power it. The IR LED sends a beam to be reflected off of the encoding disk for the photo transistor to receive and send the signal off the custom-made PCB to a Schmitt Trigger. The input high of this signal must be ≥ 2.2 Volts, the input low must be ≤ 0.6 Volts. Along with these requirements, the minimum On-Time and Off-Time of the signal must be greater than 17 microseconds each.

3.1.3 JST B5B-PH-K-S 5-Pin Connector

We will solder the JST B5B-PH-K-S five pin connector directly to our custom-made PCB, which is attached to the Grape 2 3056582-004 motor assembly. The JST B5B-PH-K-S five pin connector will have inputs of 24 Volts to power the Grape 2 3056582-004 motor assembly, 5.0 or 3.3 Volts to power the opto-reflective array, and will also have a ground connected to it. The only output coming from the JST B5B-PH-K-S connector will be from pin 2, which will be the feedback/output from the opto-reflective array. This signal will be sent to an off-board Schmitt Trigger or other signal processing circuitry.

3.1.4 Encoding Disk

We will be using many different encoding disks to find which encoding disk is the most reflective and cost efficient. Our encoding disks are made of various materials such as black nylon, white nylon, aluminum, PCB, white photo paper, and gold. These encoding disks will consist of 8, 48 or 64 windows and will be run at speeds ranging from 200 RPMs to 6000 RPMs. The encoding disk will reflect the beam from the IR LED on the opto-reflective array so the photo transistor can receive it and send the signal to the off-board Schmitt Trigger. The sensor-to-encoding disk space will be approximately .8mm. The encoding disk will be pressure-fitted to the shaft of the Grape 2 3056582-004 motor assembly.

3.1.5 Grape 2 3056582-004 Motor Assembly

0 to 24 VDC will be applied to the Grape 2 3056582-004 motor assembly to power it via the JST B5B-PH-K-S five-pin connector. The custom-made PCB will be soldered to the Grape 2 3056582-004 motor assembly. The motor will run at speeds ranging from 200 RPMs to 6000 RPMs. The encoding disk will be pressure-fitted to the shaft of the Grape 2 3056582-004 motor assembly.

4.0 Test Procedures

We will be testing various encoding disk materials combined with different opto-reflective arrays in order to find the best combination that will yield results that meet our output signal requirements. While we know the spacing between the opto-reflective array and the encoding disk will be critical in this testing, we have no requirements to maximize the collector current. Instead, our requirements are to meet the less than 0.6 VDC logic low and greater than 2.2 VDC logic high. With that being stated, we will begin with static testing, followed by dynamic testing.

4.1 Static Testing

During static testing, the motor will not be running. The main focus here is to test the reflectivity of the various encoding disk materials. We will be placing the various materials on the motor shaft, which is attached to our test fixture, apply power to the opto-reflective array, and then adjust the spacing and measure the current through the photo-transistor collector. We will test all the encoding disk materials with one array, then replace the array and repeat the procedure until we have tested each encoding disk material with each array.

Before testing each sensor, we must ensure that the sensor is properly mounted on the custom-made PCB attached to the test fixture and that the JST B5B-PH-K-S connector is properly connected to a power supply and to ground. Pin-2 will be connected to an oscilloscope to measure the output signal. Due to the pull up resistor, an area of the encoding disk with no reflection will result in a logic low output. The inverse is true for a reflective area.

4.1.1 Fairchild QRE-1113 Sensor

1. Black Nylon (original encoding disk)
    a. Place the black nylon 18B1192 on the motor shaft making sure the appropriate side is facing the QRE-1113 sensor on the test fixture. Zero the calipers and measure spacing to 0.4 mm.
    b. Apply 5 VDC power to opto-reflective array.
    c. Observe the signal on the oscilloscope and collector current on the multimeter. Ensure that a logic low is present meaning that the LED is shining on a non-reflective portion of the encoding disk.
    d. In 0.1 mm increments, increase the distance between the opto-reflective array and the QRE-1113 sensor from 0.4 mm out to 1.5 mm, recording the current level of the output signal at each distance.
    e. Turn power supply off.
    f. Remove black nylon 18B1192 from motor shaft.
2. White Nylon
    a. Place a piece of white nylon at the end of motor shaft. Zero the calipers and measure spacing to 0.4 mm.
    b. Repeat steps 1b through 1e.
    c. Remove white nylon from test fixture
3. Stamped Aluminum Disk
    a. Place the aluminum encoding disk on the motor shaft making sure the appropriate side is facing the QRE-1113 sensor on the test fixture. Zero the calipers and measure spacing to 0.4 mm.
    b. Repeat steps 1b through 1e.
    c. Remove aluminum encoding disk from test fixture.
4. Gold Sputtered 18B1192

   a. Place the gold sputtered 18B1192 on the motor shaft making sure the appropriate side is facing the QRE-1113 sensor on the test fixture. Zero the calipers and measure spacing to 0.4 mm.
   b. Repeat steps 1b through 1e.
   c. Remove gold sputtered 18B1192 from test fixture.
5. Custom Printed Circuit Board (PCB) Disk
   a. Place the custom printed circuit board disk on the motor shaft making sure the appropriate side is facing the QRE-1113 sensor on the test fixture. Zero the calipers and measure spacing to 0.4 mm.
   b. Repeat steps 1b through 1e.
   c. Remove the custom printed circuit board disk from test fixture.
6. White Photo Paper Disk
   a. Place the white photo paper disk on the motor shaft making sure the appropriate side is facing the QRE-1113 sensor on the test fixture. Zero the calipers and measure spacing to 0.4 mm.
   b. Repeat steps 1b through 1e.
   c. Remove the white photo paper disk from test fixture.

4.1.2 Osram SFH 9201 Sensor

1. Black Nylon (original encoding disk)
   a. Place the black nylon 18B1192 on the motor shaft making sure the appropriate side is facing the SFH 9201 sensor on the test fixture. Zero the calipers and measure spacing to 0.4 mm.
   b. Apply 5 VDC power to opto-reflective array.
   c. Observe the signal on the oscilloscope and collector current. Ensure that a logic low is present meaning that the LED is shining on a non-reflective portion of the encoding disk.
   d. In 0.1 mm increments, increase the distance between the opto-reflective array and the SFH 9201 sensor from 0.4 mm out to 1.5 mm, recording the current level of the output signal at each distance.
   e. Turn power supply off.
   f. Remove black nylon 18B1192 from motor shaft.
2. White Nylon
   a. Place a piece of white nylon at the end of motor shaft. Zero the calipers and measure spacing to 0.4 mm.
   b. Repeat steps 1b through 1e.
   c. Remove white nylon from test fixture
3. Stamped Aluminum Disk
   a. Place the aluminum encoding disk on the motor shaft making sure the appropriate side is facing the SFH 9201 sensor on the test fixture. Zero the calipers and measure spacing to 0.4 mm.
   b. Repeat steps 1b through 1e.

   c. Remove aluminum encoding disk from test fixture.
4. Gold Sputtered 18B1192
   a. Place the gold sputtered 18B1192 on the motor shaft making sure the appropriate side is facing the SFH 9201 sensor on the test fixture. Zero the calipers and measure spacing to 0.4 mm.
   b. Repeat steps 1b through 1e.
   c. Remove gold sputtered 18B1192 from test fixture.
5. Custom Printed Circuit Board (PCB) Disk
   a. Place the custom printed circuit board disk on the motor shaft making sure the appropriate side is facing the SFH 9201 sensor on the test fixture. Zero the calipers and measure spacing to 0.4 mm.
   b. Repeat steps 1b through 1e.
   c. Remove the custom printed circuit board disk from test fixture.
6. White Photo Paper Disk
   a. Place the white photo paper disk on the motor shaft making sure the appropriate side is facing the SFH 9201 sensor on the test fixture. Zero the calipers and measure spacing to 0.4 mm.
   b. Repeat steps 1b through 1e.
   c. Remove the white photo paper disk from test fixture.

4.1.3 Sharp GP2S24J0000F Sensor

1. Black Nylon (original encoding disk)
   a. Place the black nylon 18B1192 on the motor shaft making sure the appropriate side is facing the GPS2S24J000F sensor on the test fixture. Zero the calipers and measure spacing to 0.4 mm.
   b. Apply 5 VDC power to opto-reflective array.
   c. Observe the signal on the oscilloscope and collector current. Ensure that a logic low is present meaning that the LED is shining on a non-reflective portion of the encoding disk.
   d. In 0.1 mm increments, increase the distance between the opto-reflective array and the GPS2S24J000F sensor from 0.4 mm out to 1.5 mm, recording the current level of the output signal at each distance.
   e. Turn power supply off.
   f. Remove black nylon 18B1192 from motor shaft.
2. White Nylon
   a. Place a piece of white nylon at the end of motor shaft. Zero the calipers and measure spacing to 0.4 mm.
   b. Repeat steps 1b through 1e.
   c. Remove white nylon from test fixture
3. Stamped Aluminum Disk

   a. Place the aluminum encoding disk on the motor shaft making sure the appropriate side is facing the GPS2S24J000F sensor on the test fixture. Zero the calipers and measure spacing to 0.4 mm.
   b. Repeat steps 1b through 1e.
   c. Remove aluminum encoding disk from test fixture.
4. Gold Sputtered 18B1192
   a. Place the gold sputtered 18B1192 on the motor shaft making sure the appropriate side is facing the GPS2S24J000F sensor on the test fixture. Zero the calipers and measure spacing to 0.4 mm.
   b. Repeat steps 1b through 1e.
   c. Remove gold sputtered 18B1192 from test fixture.
5. Custom Printed Circuit Board (PCB) Disk
   a. Place the custom printed circuit board disk on the motor shaft making sure the appropriate side is facing the GPS2S24J000F sensor on the test fixture. Zero the calipers and measure spacing to 0.4 mm.
   b. Repeat steps 1b through 1e.
   c. Remove the custom printed circuit board disk from test fixture.
6. White Photo Paper Disk
   a. Place the white photo paper disk on the motor shaft making sure the appropriate side is facing the GPS2S24J000F sensor on the test fixture. Zero the calipers and measure spacing to 0.4 mm.
   b. Repeat steps 1b through 1e.
   c. Remove the white photo paper disk from test fixture.

4.2 Dynamic Testing

Now we will apply power to the motor and test the shaft encoder with the motor running at speeds of 6000 RPM and at 200 RPM. These are the max/min requirements Lexmark wanted us to test. We will be performing almost the same procedure as the static tests, only now the motor will be running to simulate actual performance within a printer.

In this portion of the testing, we will be using a spray painted 18B1192 encoding disk to simulate a white nylon. We could not fabricate an encoding disk out of white nylon within our time restraints for this project.

It is important to take note that during this portion of our testing we will be drawing conclusions from our static test results to decipher the best method of approaching the dynamic test. While the static test focused primarily on the separation between the encoding disk and opto-reflective array as well as the max collector current, this section focuses on the voltage levels of the output signal. This is determined by the current passing through a pull-up resistor on the PCB.

4.2.1 Fairchild QRE-1113 sensor

1. Black Nylon (original encoding disk)

   a. Place the black nylon 18B1192 on the motor shaft making sure the appropriate side is facing the QRE-1113 sensor on the test fixture. Zero the calipers and measure out to the distance that gave us the peak current from the static testing.
   b. Apply 5 VDC power to opto-reflective array and apply 24 VDC power and ground to Grape2 3056582-004 motor.
   c. Observe the signal on the oscilloscope. Ensure the frequency reading of the pulse train is around 6.45 kHz to meet the required RPM speed of 6000 +/- 150.
   d. In 0.1 mm increments, increase the distance between the opto-reflective array and the QRE-1113 sensor until the signal becomes attenuated and doesn't meet the requirements. Record the max distance at which the signal meets the requirements.
   e. Observe the signal while running the motor. Take a single screen capture of the pulse train and measure the max/min of the signal to ensure that high is greater than 2.2 VDC and the low is less than 0.6 VDC.
   f. Repeat steps 1c through 1e running the motor at 200 RPM.
   g. Turn power supply off.
   h. Repeat steps 1b through 1f using 3.3 VDC.
   i. Remove black nylon 18B1192 from motor shaft.
2. White Nylon
   a. Place a piece of white nylon at the end of motor shaft. Zero the calipers and measure out to the distance that gave us the peak current from the static testing.
   b. Repeat steps 1b through 1h.
   c. Remove white nylon from test fixture
3. Stamped Aluminum Disk
   a. Place the aluminum encoding disk on the motor shaft making sure the appropriate side is facing the QRE-1113 sensor on the test fixture. Zero the calipers and measure out to the distance that gave us the peak current from the static testing.
   b. Repeat steps 1b through 1h.
   c. Remove aluminum encoding disk from test fixture.
4. Gold Sputtered 18B1192
   a. Place the gold sputtered 18B1192 on the motor shaft making sure the appropriate side is facing the QRE-1113 sensor on the test fixture. Zero the calipers and measure out to the distance that gave us the peak current from the static testing.
   b. Repeat steps 1b through 1h.
   c. Remove gold sputtered 18B1192 from test fixture.
5. Custom Printed Circuit Board (PCB) Disk
   a. Place the custom printed circuit board disk on the motor shaft making sure the appropriate side is facing the QRE-1113 sensor on the test fixture. Zero the calipers and measure out to the distance that gave us the peak current from the static testing.
   b. Repeat steps 1b through 1h.
   c. Remove the custom printed circuit board disk from test fixture.
6. White Photo Paper Disk

a. Place the white photo paper disk on the motor shaft making sure the appropriate side is facing the QRE-1113 sensor on the test fixture. Zero the calipers and measure out to the distance that gave us the peak current from the static testing.
b. Repeat steps 1b through 1h.
c. Remove the white photo paper disk from test fixture.

4.2.2 Osram SFH 9201 Sensor

1. Black Nylon (original encoding disk)
    a. Place the black nylon 18B1192 on the motor shaft making sure the appropriate side is facing the SFH 9201 sensor on the test fixture. Zero the calipers and measure out to the distance that gave us the peak current from the static testing.
    b. Apply 5 VDC power to opto-reflective array and apply 24 VDC power and ground to Grape2 3056582-004 motor.
    c. Observe the signal on the oscilloscope. Ensure the frequency reading of the pulse train is around 6.45 kHz to meet the required RPM speed of 6000 +/- 150.
    d. In 0.1 mm increments, increase the distance between the opto-reflective array and the SFH 9201 sensor until the signal becomes attenuated and doesn't meet the requirements. Record the max distance at which the signal meets the requirements.
    e. Observe the signal while running the motor. Take a single screen capture of the pulse train and measure the max/min of the signal to ensure that high is greater than 2.2 VDC and the low is less than 0.6 VDC.
    f. Repeat steps 1c through 1e running the motor at 200 RPM.
    g. Turn power supply off.
    h. Repeat steps 1b through 1f using 3.3 VDC.
    i. Remove black nylon 18B1192 from motor shaft.
2. White Nylon
    a. Place a piece of white nylon at the end of motor shaft. Zero the calipers and measure out to the distance that gave us the peak current from the static testing.
    b. Repeat steps 1b through 1h.
    c. Remove white nylon from test fixture
3. Stamped Aluminum Disk
    a. Place the aluminum encoding disk on the motor shaft making sure the appropriate side is facing the SFH 9201 sensor on the test fixture. Zero the calipers and measure out to the distance that gave us the peak current from the static testing.
    b. Repeat steps 1b through 1h.
    c. Remove aluminum encoding disk from test fixture.
4. Gold Sputtered 18B1192
    a. Place the gold sputtered 18B1192 on the motor shaft making sure the appropriate side is facing the SFH 9201 sensor on the test fixture. Zero the calipers and measure out to the distance that gave us the peak current from the static testing.
    b. Repeat steps 1b through 1h.

   c. Remove gold sputtered 18B1192 from test fixture.
5. Custom Printed Circuit Board (PCB) Disk
   a. Place the custom printed circuit board disk on the motor shaft making sure the appropriate side is facing the SFH 9201 sensor on the test fixture. Zero the calipers and measure out to the distance that gave us the peak current from the static testing.
   b. Repeat steps 1b through 1h.
   c. Remove the custom printed circuit board disk from test fixture.
6. White Photo Paper Disk
   a. Place the white photo paper disk on the motor shaft making sure the appropriate side is facing the SFH 9201 sensor on the test fixture. Zero the calipers and measure out to the distance that gave us the peak current from the static testing.
   b. Repeat steps 1b through 1h.
   c. Remove the white photo paper disk from test fixture.

4.2.3 Sharp GP2S24J0000F Sensor

1. Black Nylon (original encoding disk)
   a. Place the black nylon 18B1192 on the motor shaft making sure the appropriate side is facing the GP2S24J0000F sensor on the test fixture. Zero the calipers and measure out to the distance that gave us the peak current from the static testing.
   b. Apply 5 VDC power to opto-reflective array and apply 24 VDC power and ground to Grape2 3056582-004 motor.
   c. Observe the signal on the oscilloscope. Ensure the frequency reading of the pulse train is around 6.45 kHz to meet the required RPM speed of 6000 +/- 150.
   d. In 0.1 mm increments, increase the distance between the opto-reflective array and the GP2S24J0000F sensor until the signal becomes attenuated and doesn't meet the requirements. Record the max distance at which the signal meets the requirements.
   e. Observe the signal while running the motor. Take a single screen capture of the pulse train and measure the max/min of the signal to ensure that high is greater than 2.2 VDC and the low is less than 0.6 VDC.
   f. Repeat steps 1c through 1e running the motor at 200 RPM.
   g. Turn power supply off.
   h. Repeat steps 1b through 1f using 3.3 VDC.
   i. Remove black nylon 18B1192 from motor shaft.
2. White Nylon
   a. Place a piece of white nylon at the end of motor shaft. Zero the calipers and measure out to the distance that gave us the peak current from the static testing.
   b. Repeat steps 1b through 1h.
   c. Remove white nylon from test fixture
3. Stamped Aluminum Disk

   a. Place the aluminum encoding disk on the motor shaft making sure the appropriate side is facing the GP2S24J0000F sensor on the test fixture. Zero the calipers and measure out to the distance that gave us the peak current from the static testing.
   b. Repeat steps 1b through 1h.
   c. Remove aluminum encoding disk from test fixture.
4. Gold Sputtered 18B1192
   a. Place the gold sputtered 18B1192 on the motor shaft making sure the appropriate side is facing the GP2S24J0000F sensor on the test fixture. Zero the calipers and measure out to the distance that gave us the peak current from the static testing.
   b. Repeat steps 1b through 1h.
   c. Remove gold sputtered 18B1192 from test fixture.
5. Custom Printed Circuit Board (PCB) Disk
   a. Place the custom printed circuit board disk on the motor shaft making sure the appropriate side is facing the GP2S24J0000F sensor on the test fixture. Zero the calipers and measure out to the distance that gave us the peak current from the static testing.
   b. Repeat steps 1b through 1h.
   c. Remove the custom printed circuit board disk from test fixture.
6. White Photo Paper Disk
   a. Place the white photo paper disk on the motor shaft making sure the appropriate side is facing the GP2S24J0000F sensor on the test fixture. Zero the calipers and measure out to the distance that gave us the peak current from the static testing.
   b. Repeat steps 1b through 1h.
   c. Remove the white photo paper disk from test fixture.

5.0 Requirements Traceability

This section will briefly review what our system requirements are for this project and then show through test results and observations how we are meeting each requirement. For our project, we are required to meet the following criteria:

5.1 Functional Requirements

		Requirement	Project Design
Input	Motor power Opto-reflective array power Ground	24 VDC 5 or 3.3 VDC Present	24 VDC 5 VDC & 3.3 VDC Present
Output	High Low On-time Off-time Pulse width	O.H. ≥ 2.2 VDC O.L. ≤ 0.6 VDC O.T. ≥ 17 µs O.T. ≥ 17 µs Period ≥ 34 µs	TBD TBD TBD TBD TBD
Encoding Disk	CPR	8, 48 or greater	8, 48, & 64 window encoding disks used in testing
Motor RPM	Maximum Minimum	6000 +/- 150 RPM 200 RPM	6000 +/- RPM 200 RPM

5.2 Design Constraints

		Requirement	Project Design
Environmental Impact		Little to none	No measureable impact
Safety	Circuit Flame class 94V0	RoHS compliant Materials meet requirements specified in Reference section	All parts RoHS compliant
Temperature		0°C ≤ T ≤ 50°C	Ambient nor junction temperature reached 50°C
EMC testing		EMC testing to be performed once solution is reached	N/A
PCB	Length Width Height	≤ 37.0 mm ≤ 30.5 mm ≤ 14.0 mm	25.4 mm (1 inch) 25.4 mm (1 inch) 12 mm

6.0 References

Flame Class 94V-0

"UL Test Procedures." *Specifications*. Web. 14 Feb. 2011. <http://www.portplastics.com/download/pdf/plastics/techspecs/techspecs24.pdf>.

"UL94 Flammability Test Method Overview." *Boedeker Plastics*. 2011. Web. 14 Feb. 2011. <http://www.boedeker.com/bpi-ul94.htm>.

Sensors

OSRAM SFH 9201

See Appendix A

Fairchild QRE1113

See Appendix B

Sharp GP2S24J000F

See Appendix C

5-Pin Connector

JST B5B-PH-K-S

See Appendix D

Motor

Grape2 3056582-004

See Appendix E

Calipers

Cen-tech model 47256

See Appendix F

Encoding Disk

18B1192

See Appendix G