MTRE 2610 Engineering Algorithms and Visualization – Dr. Kevin McFall

Laboratory – Pneumatics and Active Light Sensors

Introduction

Work continues this week on the color sorting robot depicted in Figure 1. The completed system involves all the major elements listed below:

A. Motor to rotate arm
B. Switch for rotary encoder
C. Limit switch to determine home position
D. Air compressor
E. Solenoid valve for generating suction
F. Solenoid valve for lowering arm
G. Piston-cylinder driving vacuum
H. Piston-cylinder delivering vacuum
I. Piston-cylinder to lower arm
J. Light source for part detection
K. Phototransistor for part detection
L. Analog color sensor
M. Cable channels
N. Proprietary Fischertechnik microcontroller to be replaced with an Arduino Uno

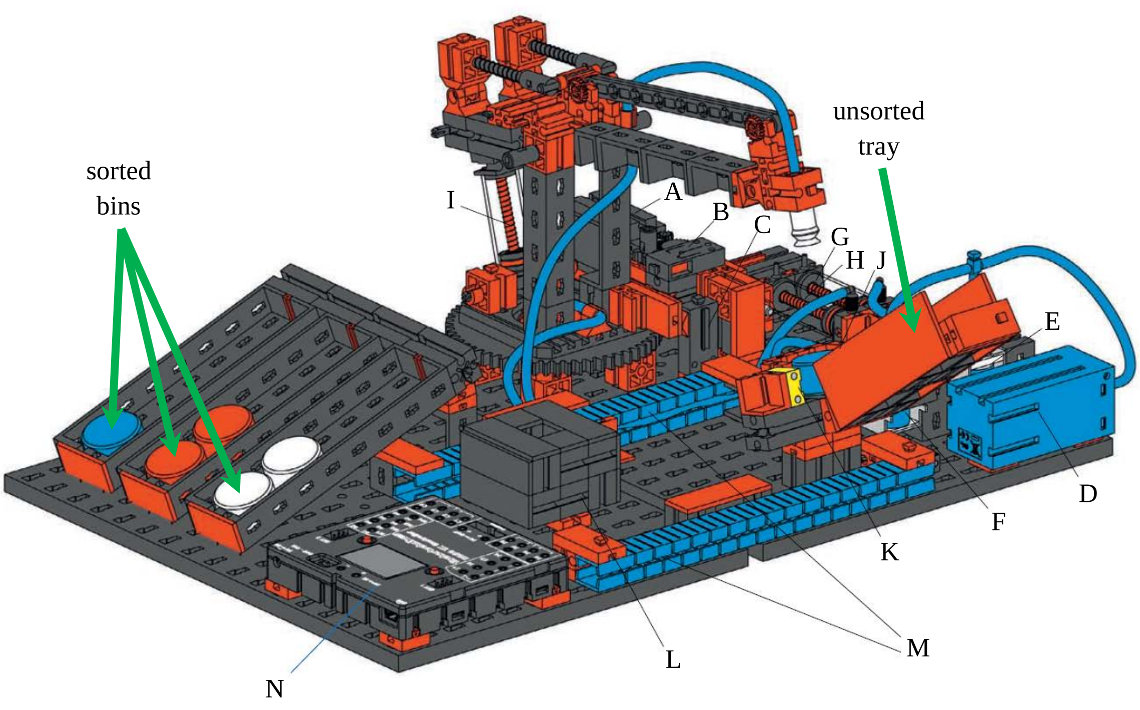

Figure 1: Schematic of completed color sorting robot including major elements.

This laboratory exercise deals with the remaining sensor and actuator components, specifically pneumatic elements D-I and the active light sensor elements J-L. These elements will be incorporated into the previously completed motion control to complete color sorting robot operation.

Reattaching pneumatic hoses

The previous laboratory exercise restricted motion of the robotic arm between the unsorted tray and sorted bins. The pneumatic hoses and suction cup in Figure 2 can now be reattached so that lowering the arm and picking up parts in the unsorted tray.

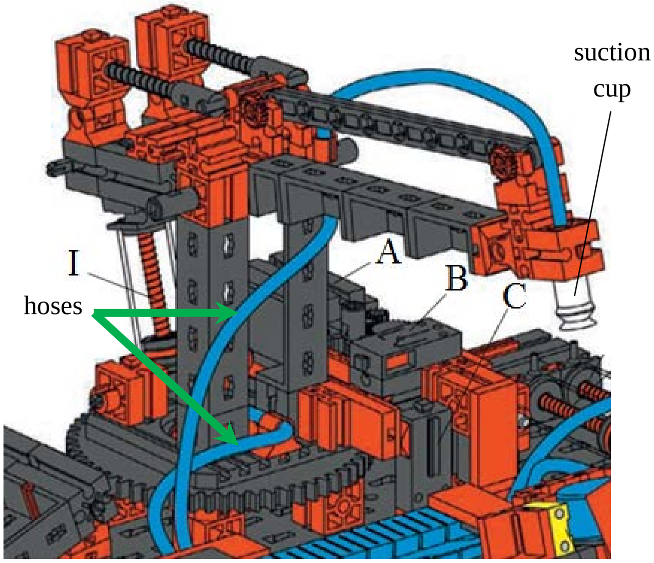

Figure 2: Hoses and suction cup to be reattached before operating the pneumatic system.

Pneumatic actuators

While motors are convenient to actuate by simply applying an analog voltage, they do not generate large forces and cannot produce near-instantaneous linear motion. For these types of applications, pneumatic systems based on compressed air are more appropriate. The color sorting robot contains a small air compressor, illustrated in Figure 2. The passage of air is controlled by solenoid valves, also pictured in Figure 2. Solenoids operate by generating a magnetic field when voltage, 9 V in this case, is applied across their leads. This field exerts a force on the solenoid's magnetic core. A spring holds the core in place to block flow between the ports, but the magnetic force moves the core, opening a channel for air to flow. Essentially, the solenoid blocks flow between the ports unless a voltage is applied across the leads.

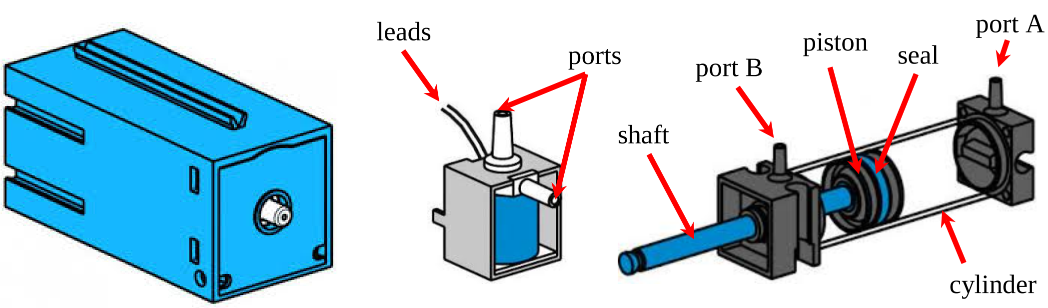

Figure 2: Elements comprising the pneumatic system include the compressor element D (left), solenoid valve elements E and F (middle), and piston/cylinder elements G, H, and I (right).

Unfortunately, solenoids on the color sorting robot require 9 V to trigger and substantial current to activate, eliminating the possibility of connecting them directly to an Arduino digital output pin. However, they can be driven using a transistor just as the DC motor was in the first laboratory exercise. As an alternative, Figure 3 illustrates how to connect the solenoid using a wire with built-in transistor.

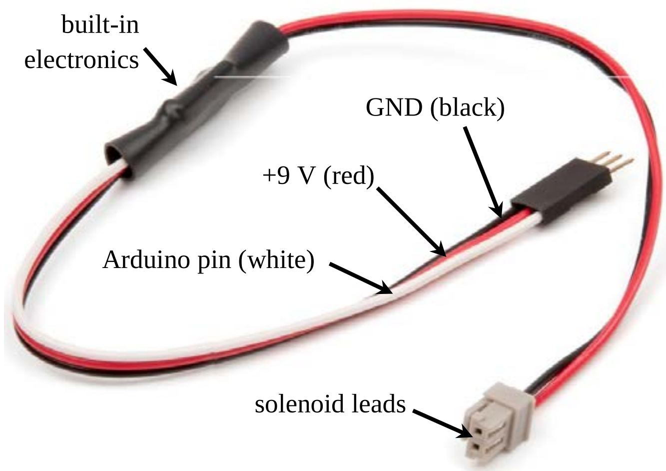

Figure 3: Connecting wire with transistor previous used to drive a DC motor, modified for the solenoid valve.

Solenoid valves are used to control whether air flows or not to the piston/cylinder assemblies appearing in Figure 2. The piston seal mates closely with the surrounding cylinder, preventing air passage from one side of the piston to the other. These cylinders are dual acting in that a port is installed on both sides of the piston, allowing air to press the piston, and the attached shaft, in either direction. However, the cylinders on the color sorting robot are modified, with a spring, to be only single acting. Air hoses are only attached the A ports, with the spring installed to return the piston to the port A end when air is not applied.

Channeling compressed air to the piston/cylinder on the robot arm lowers it the appropriate distance to pick up parts in the unsorted tray, place them on the color sensor, and drop them in the sorted bins. Applying a vacuum to the suction cup to pick up parts is not as straightforward. The compressor generates the positive pressure, i.e. one higher than atmospheric, used to *push* the piston and shaft on the robotic arm. Pneumatic suction for *pull*ing on the parts normally requires a vacuum pump to generate negative pressure, i.e. less than atmospheric. Rather than supplying the color sorting robot with both compressor and vacuum pump, a positive pressure can be used to pull a vacuum a two piston/cylinder arrangement.

The configuration in Figure 4 converts a positive pressure on the pressure line to a negative pressure on the vacuum line by connecting the shafts of both pistons so that the movement of one causes motion of the other. Applying a positive pressure on the pressure line pulls the shaft out of the other cylinder, generating a vacuum on the other side of the piston under assumption the other end of the vacuum line is not open to the atmosphere. If initiated when the suction cup is pressed against a part, the resulting vacuum generates sufficient force to lift the weight of the part.

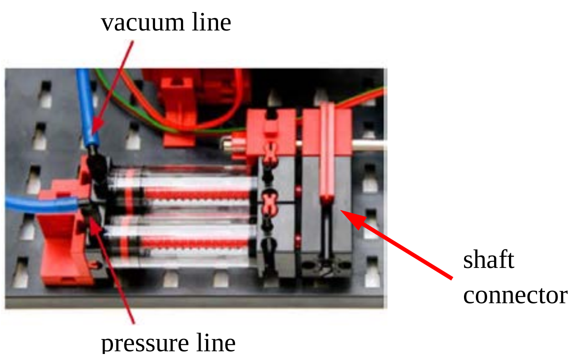

Figure 4: Dual piston/cylinder arrangement used to convert a positive pressure to a vacuum.

Phototransistor

Once the robot has emptied the unsorted tray of parts by placing them in the sorted bins, it should wait to move until another part is placed in the tray. This is accomplished using the phototransistor in Figure 5. Recall the standard transistors used in the first laboratory exercise. Normally, the emitter and collector act approximately like an open circuit, i.e. no electrical connection between the two. When a voltage is applied to the base, however, a channel opens and the emitter/collector act approximately like a short circuit, i.e. a connection with zero resistance. The phototransistor operates in the same manner although a strong light opens the channel rather than an applied voltage. The +/– terminals in Figure 5 take the place of emitter and collector, while the light collector serves as the "base". Treat the phototransistor like any other switch when connecting it to the Arduino; connect the – terminal to ground and the + terminal to power via a pull-up resistor.

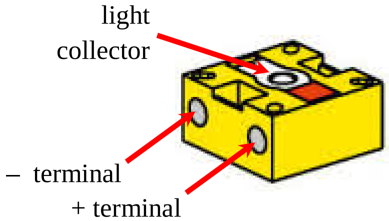

Figure 5: Phototransistor element K which operates as a light controlled switch.

This phototransistor is termed an active light sensor since the shadow from ambient light cast by a part in the unsorted tray is insufficient to change the transistor state. Rather, light must actively be shone on the phototransistor from an artificial source, light element J in this case. A state change occurs when a part is placed in the tray and blocks the light beam from reaching the phototransistor.

Analog color sensor

The color sensor depicted in Figure 6 is also an active device; it shines a red-colored LED and measures the intensity of light reflected back by the part. Because the LED emits only red wavelengths of light, different color parts absorb varying amounts of the light. The intensity reflected back will therefore depend on part color. The black plastic housing surrounding the sensor can be lifted off to better examine the sensor. The housing, with its small opening, ensures that light reaching the collector results primarily from reflection off the part since the black housing color absorbs light from essentially all wavelengths.

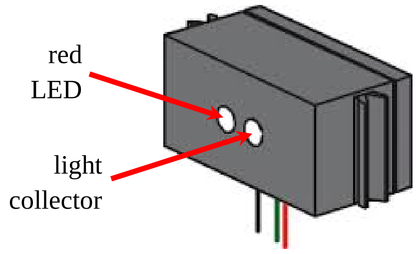

Figure 6: Analog color sensor used for part classification.

The color sensor is powered with 9 V and ground on the red and black leads, respectively, and the signal on the black lead is an analog voltage proportional to the collected light intensity. Distinguishing between red and white parts requires careful calibration, even though white reflects all light and red reflects only red wavelengths. Since the LED emits mostly red wavelength light, the reflections from white and red parts will look similar, although sufficiently different for successful classification.

Laboratory exercise procedure

Connect solenoid valve F to the Arduino digital output pins according to Figure 3. Build upon the modes of motor motion from the previous laboratory to lower the arm to the unsorted tray, color sensor, and sorted bins. Continuously serve power to the compressor during robot operation.

Include solenoid valve E using another connecting wire in order to pull a vacuum on the suction cup. Engage suction after the arm is lowered to the unsorted tray and release the part in the sorted bin.

Connect the phototransistor to an Arduino digital input like an ordinary switch while ensuring correct polarity. Use this “switch” value to pause the arm over the unsorted tray is a part is not present. Continuously serve power to light element J.

The color sorting robot is now nearly complete – all parts are placed in the same sorted bin regardless of color. Display the analog value from the color sensor using the serial monitor. Be sure to add a sufficiently long pause to read the value when parts are placed on the sensor. Some adjustment of the sensor position may be necessary to center parts over the sensor housing cavity. Record the values for several parts of each color, and decide on thresholds for discriminating the three colors. Program the distance travelled from color sensor to sorted bin to depend on the value read from each part. Adjust position of each sorted bin so that parts are directly dropped in bins. The color sorting robot is now complete!

Grading rubric

1. 25 points: Robotic arm lowers at the unsorted tray, color sensor, and sorted bins
2. 25 points: Suction lifts part out of the unsorted tray, and part released in sorted bin
3. 25 points: Arm waits above unsorted tray if it is empty
4. 25 points: Color sensor identifies part color so that parts are correctly placed in the appropriate bin