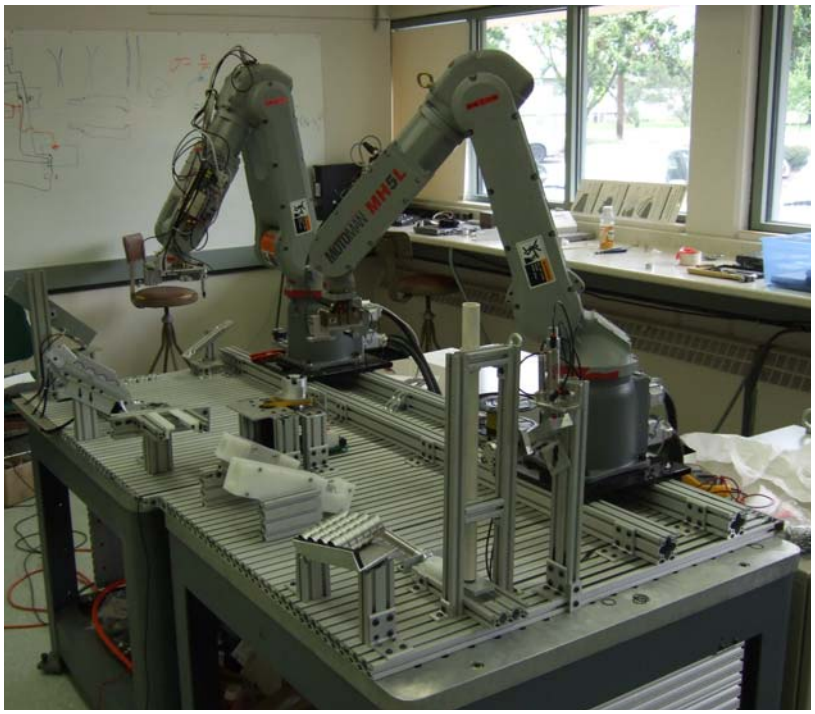

# Final Report

## ENGR 480 Manufacturing

Team: Dual Robot Arms
Members:
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David Robbins
Tim Van Arsdale
Tyler Anderson
Tyler Star

# Table of Contents

## Introduction:

The class manufactured a single-cell flashlight. This flashlight has an all-aluminum, sealed body, with a magnetic switch, a Cree XR-E light-emitting diode, and a 3.6V rechargeable LiFePO4 battery. The components of the body were produced on a Mori Seiki DuraTurn 2050 CNC turning center, and the flashlight was assembled using a custom automation system.

The custom automation system for this team included the use of two Motoman Robotic arms. The arms picked up and placed components to assemble the flashlight.

## Instructions:

1. Starting the Machine
    a. Turn on the Motoman robot controllers and allow them to fully boot
    b. Load and start JOB: master on left robot
    c. Load and start JOB: flashlight on right robot
    d. Turn on the PLC
    e. Plug in the pneumatic air
    f. Check to make sure all parts are ready to be indexed
    g. Press the Green Button to start cycle (located near the base of the left robot)

2. loading the Machine
    a. Place the components in their respective feeders
        i. Nose piece
        ii. Small O-ring
        iii. Lens
        iv. Heat sink
        v. Snap ring
        vi. Large O-ring
        vii. The metal magnetic ring
        viii. Body

3. Observe Robots During Operation
    a. If a potential problem is detected, press hold on both robots
    b. It a collision is imminent, or occurs, press both robot E-stops.

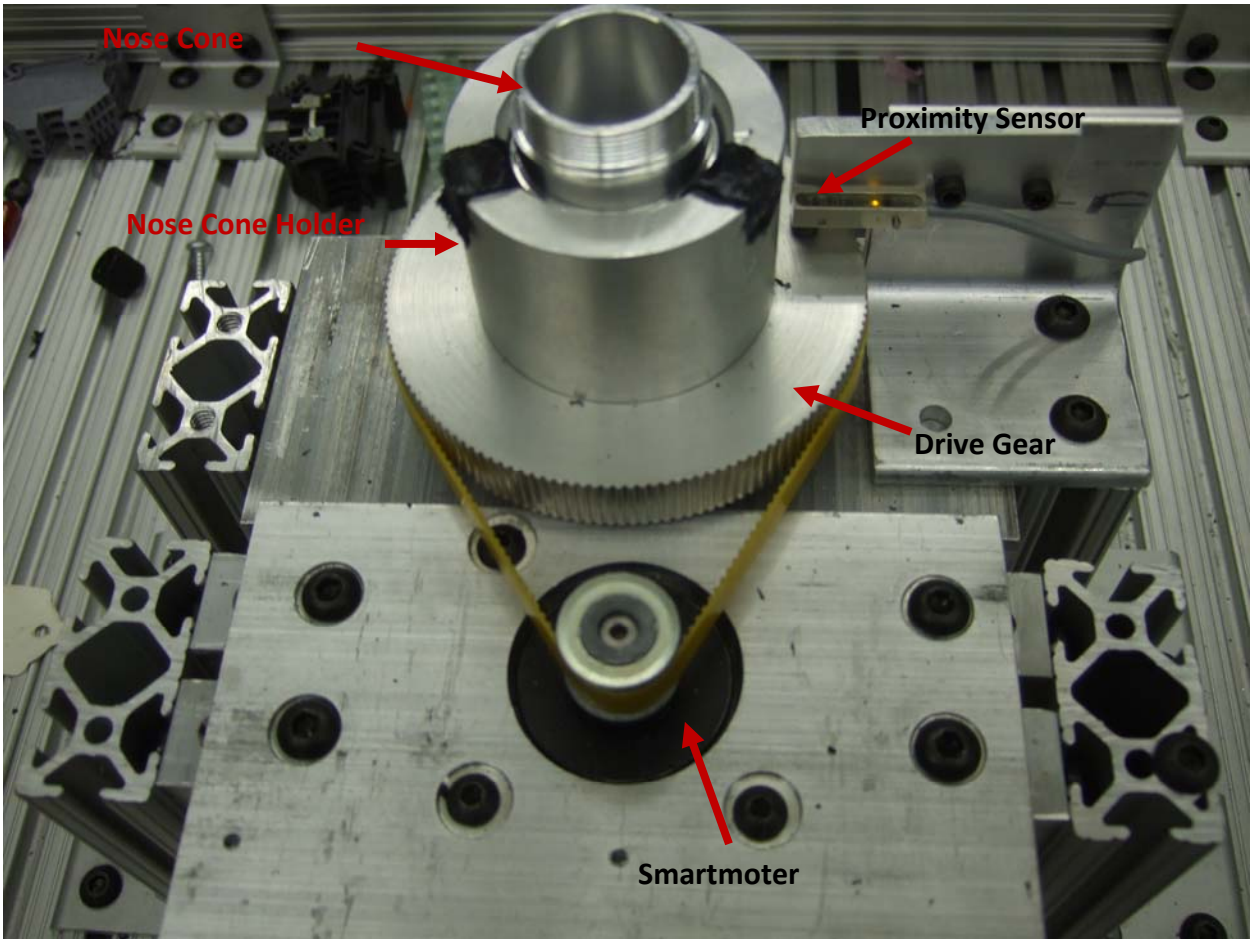
4. Clearing Jams

    a. Press both E-stops before attempting to clear Jams, Clearing Jams may cause robots to start moving with additional input from the user
    b. Clear physical jams
    c. Check for damage
    d. Check that feeders are in correct state
    e. Continue operation be restarting both robots

# Description of System Parts

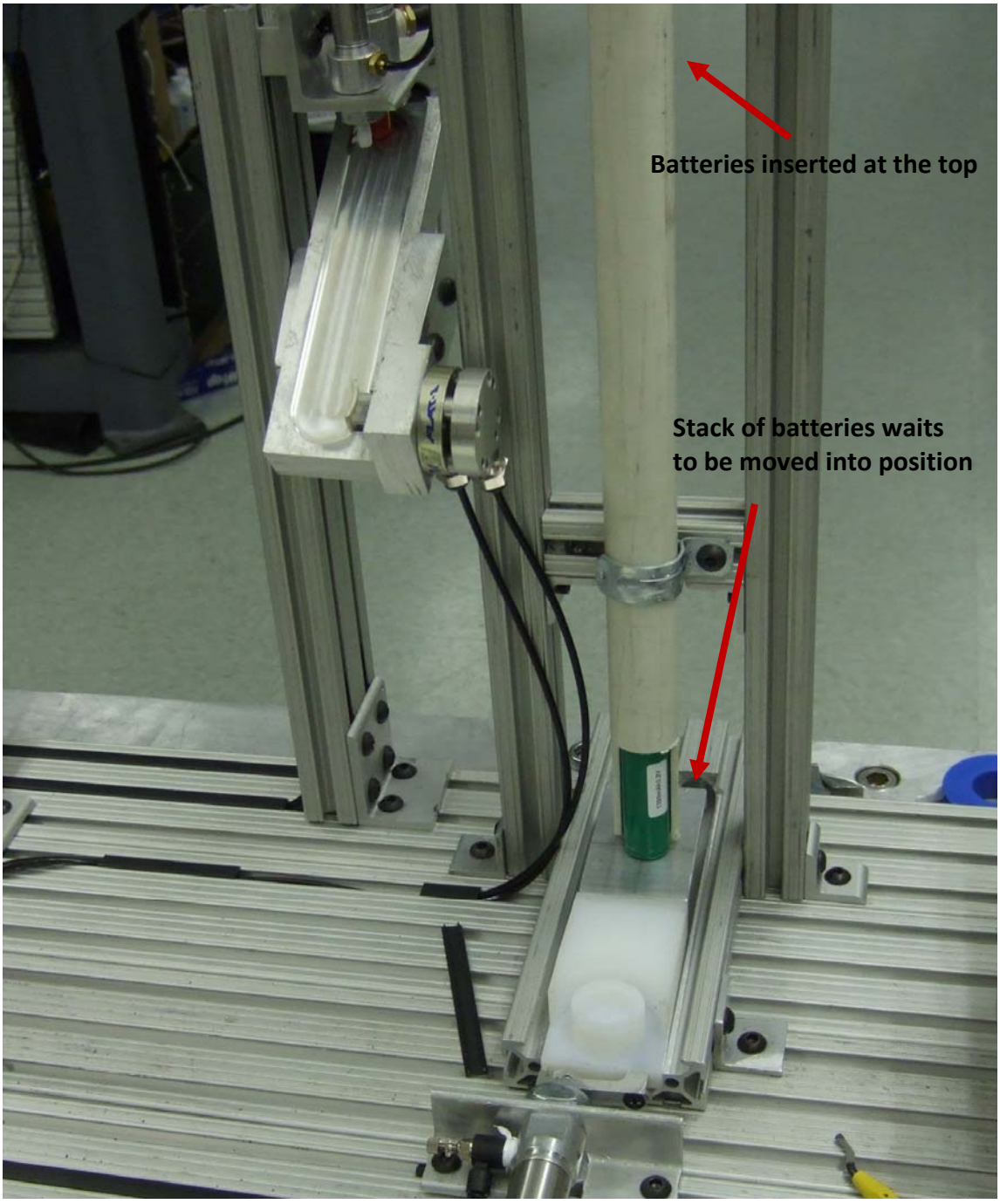
## Central Assembly Area

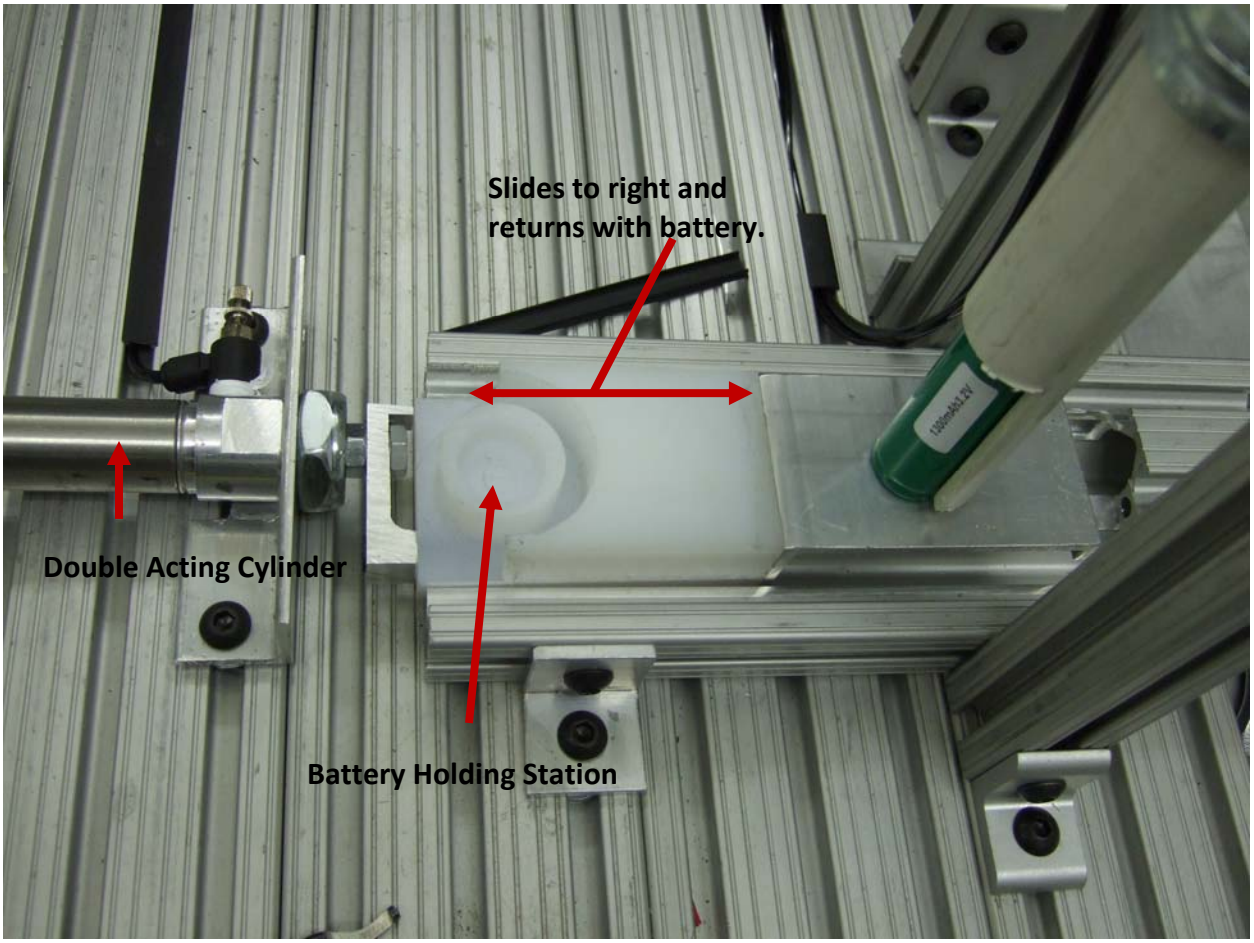
The central assembly area consists of a machined holder for the flashlight nosecone mounted to a gear and bearing which are turned by a smartmotor. The robots bring the pieces of the flashlight to this location and place them into the nose cone. After all of the pieces are in the cone, the body with the battery inside is brought in and the smartmotor turns the nosecone holder. This screws the flashlight together and finishes its assembly. The finished flashlight is then removed. To guarantee repeatability, a proximity sensor was installed to detect a screw on the gear. This, along with some programming, locates the nose cone holder in the same location for each cycle.



## Battery Feeder

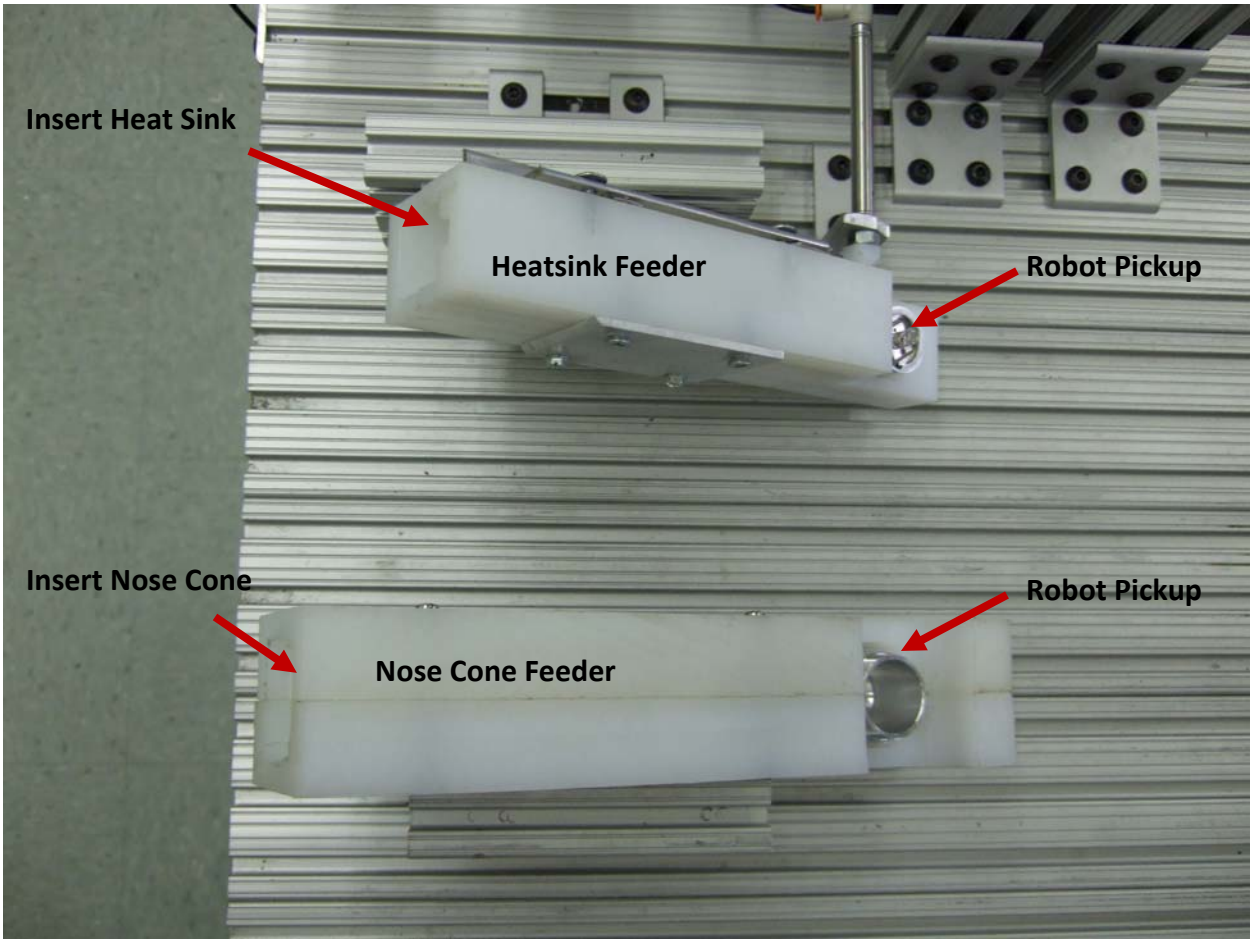
The battery feeder is constructed with four main parts. The first is a PVC tube mounted vertically in which the batteries are queued for use. The second is a double acting pneumatic cylinder which moves the third piece, a carriage. The carriage bring a battery, vertically on its end, from the PVC tube and out in the open. From this location the robot is able to pick it up inside of the flashlight tailpiece. The last part of the feeder is the guide and support structure. This feeder is directly controlled from the plc.

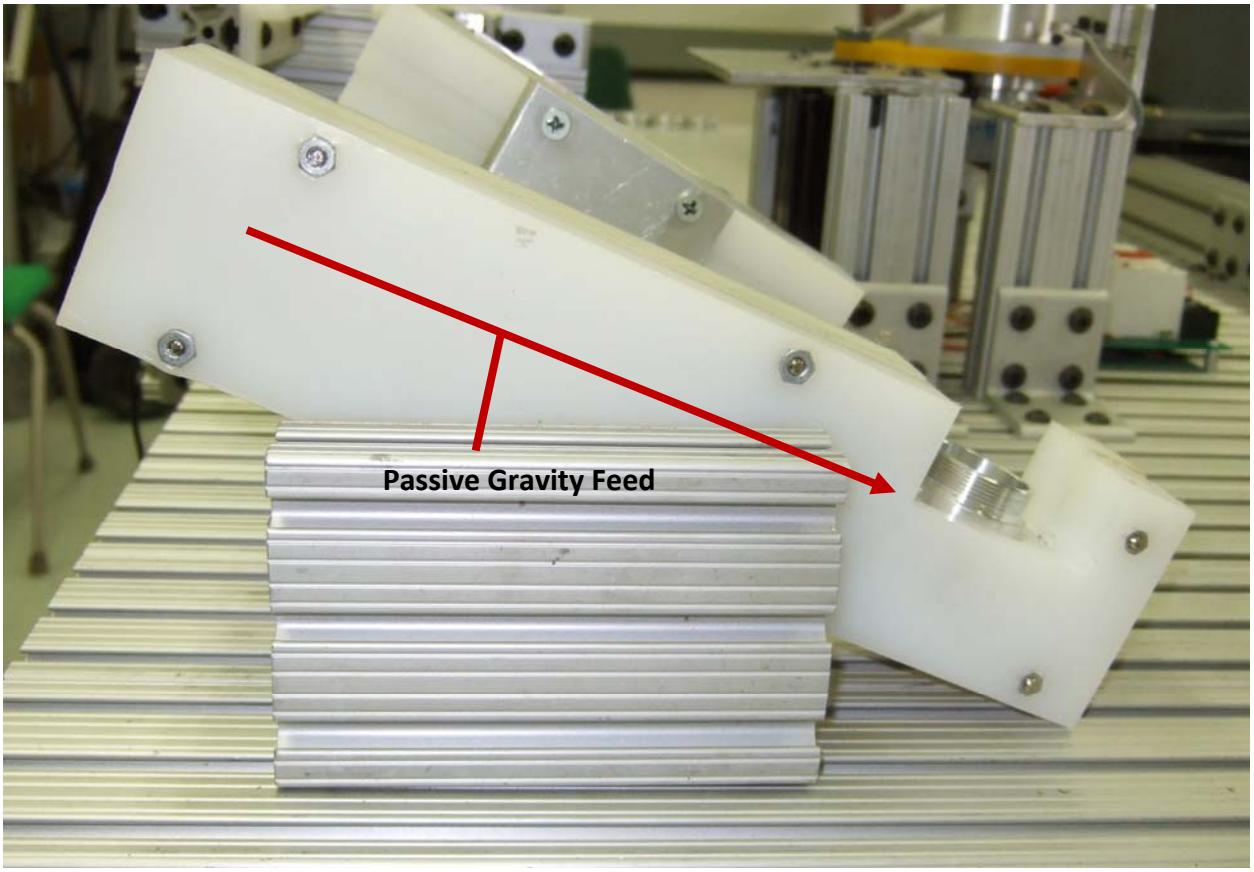


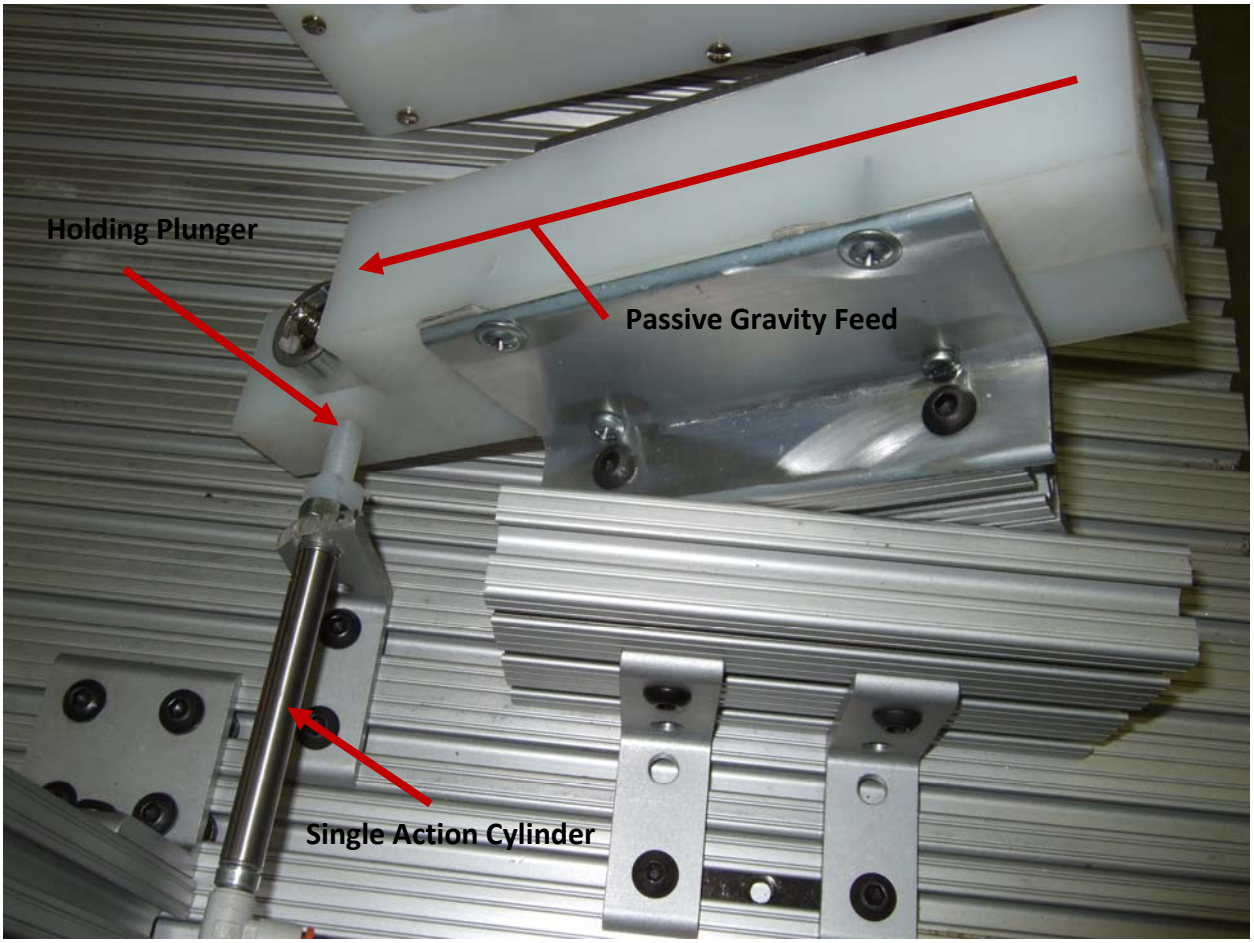

Slides to right and
returns with battery.
Double Acting Cylinder
Battery Holding Station

## Nose Cone and Heat sink Feeders

Both the nose cone and heat sink feeders are of the same basic design. One half of the profile of the each part was machined into a block of plastic. The halves were then joined together to create a path for the part to slide. Because it is made out of the profile of the part, it automatically guarantees that the parts are input in the correct orientation. The parts slide, under the force of gravity, to the end of the feeder where an opening allows the robot gripper to pick up one at a time. Because the heat sink contains a steel spring, and the robot gripper has an imbedded magnet, a single action cylinder was installed at the end of the feeder. This cylinder is connected to the robot and pinches the heat sink in place until the gripper is closed. This prevents it from being sucked up by the magnet.

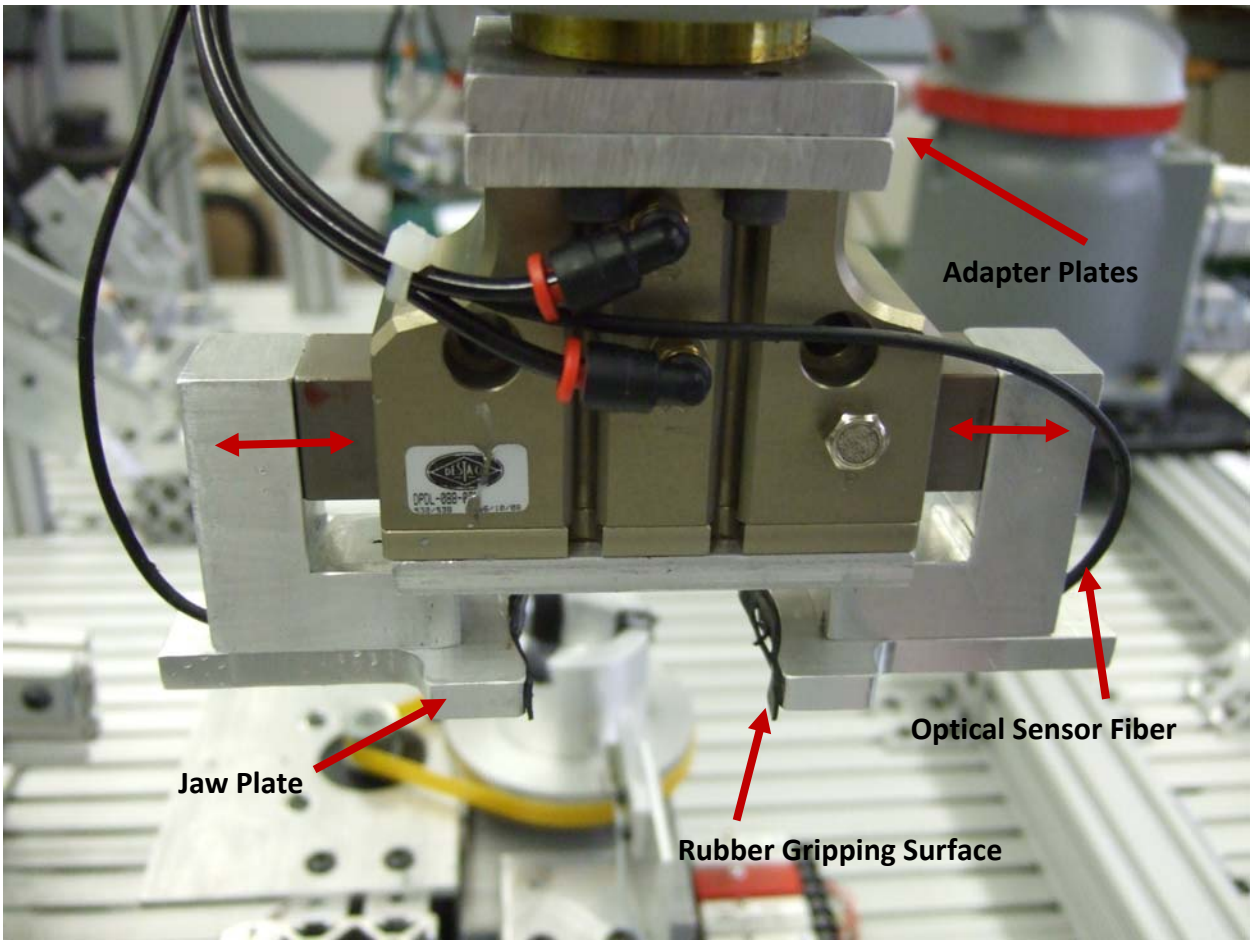



Passive Gravity Feed


Holding Plunger
Passive Gravity Feed
Single Action Cylinder

## Robot Gripper (Right Robot)

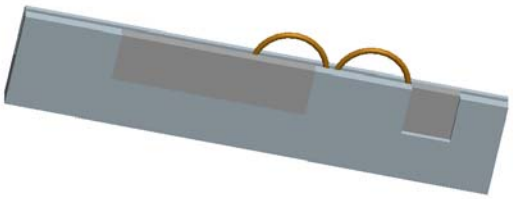
The gripper on the right robot was design to be simple but robust. It consists of a premade gripper pneumatic cylinder which provided the linear motion required for the gripper. Two solid mounting adapters go between the pneumatic gripper and the jaws. They were constructed to provide protection against being bent in the case of a crash. The Jaws were machined out of ¼" aluminum plate, and rubber was attached to the gripping surface. To guarantee correct assembly, a through beam optical sensor was installed under the Jaw plates. This allowed the robot to check whether or not a part was in the gripper. Also, two adaptor plates were required to mount the pneumatic gripper onto the robot arm.



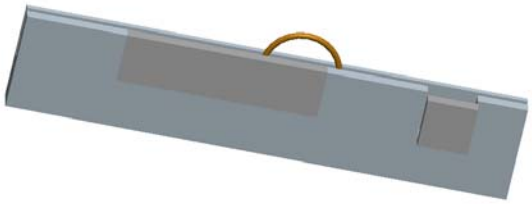
## Small O-ring Feeder

The method of feeding small o-rings involved an angled channel affixed to a base. The channel was constructed from two pieces of 1/8th " X 1 ½ " X 6" aluminum stock. The first had a recessed cut that was the width of the o-ring, allowing it to role between the two pieces. The second had two openings cut into it to allow air-powered clamps to singulate the o-rings during production. The feeding sequence went as follows:

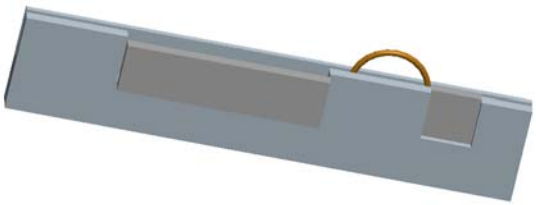
1. Both clamps are initially extended



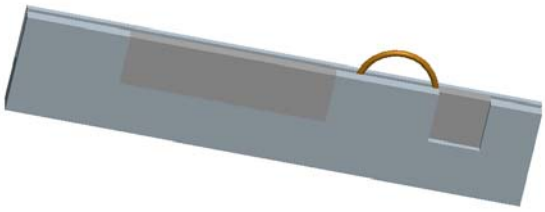
2. The lower clamp retracts and a single o-ring advances into the base



3. The lower clamp extends and the upper clamp retracts. Now all the parts that are loaded in the machine advance by one position

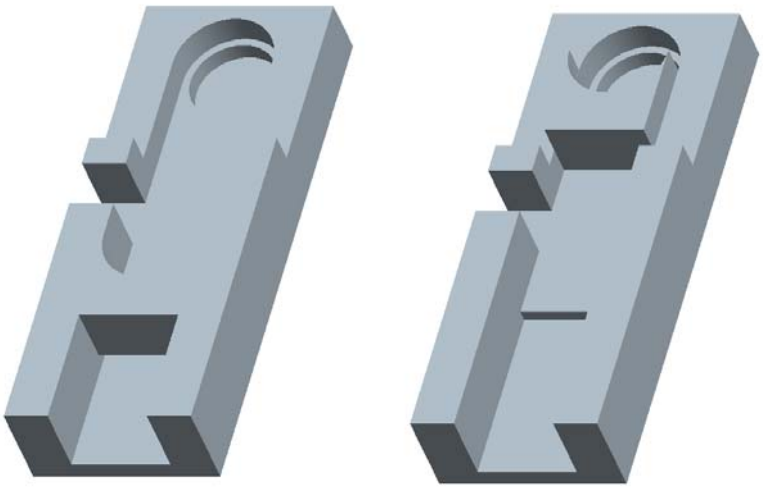


4. The upper clamp extends and the process repeats



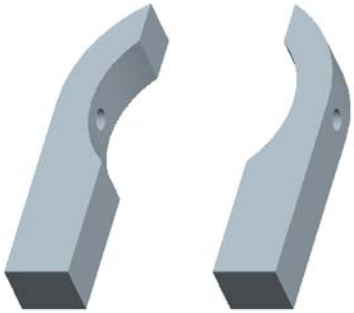
To load o-rings into the feeder, simply activate the upper air cylinder and place rings in the channel.

Once an o-ring leaves the feeder, it rolls into the base through the opening on the left side. The base was cnc milled from a piece of aluminum approximately 3” X 1.5” X.75”. Once the ring has had enough time to settle down and lay flat, the air cylinder activates and the plunger pushes the ring to its final position before being picked up. In order prevent the tool from colliding with the base, a hole was placed where the ring sits. This allows the tool to press into the o-ring and avoid unwanted contact. The figures below show the base with the plunger in both the retracted and extended positions. It should be noted that the plunger must be retracted before the tool may pick up a ring.

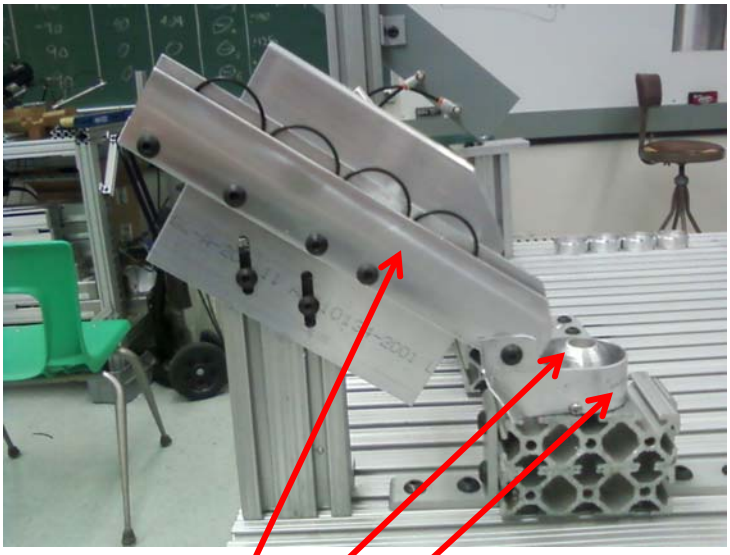


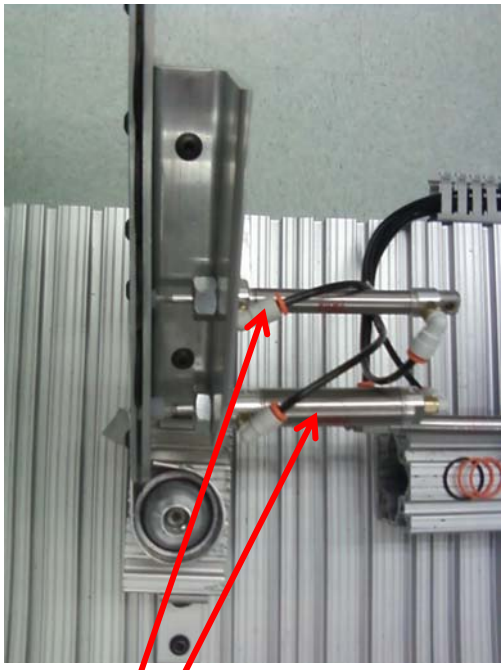
## Magnet Ring Gripper

The tool used to grab and place the on/off ring entailed two pincers mounted on a pnuematic gripper. With the gripper deactivated, the jaws would extend wide enough to allow the ring to pass between the tips. Fiber optic sensors were placed in the jaws in order to ensure that the jaws remain open until a part was clearly in the position to be grasped.



## Large O-Ring Feeder:





Feeding Channel

Positioning Cone

Positioning Fence

Upper Singulation Cylinder

Lower Singulation Cylinder

The large o-ring has an inner diameter of approximately 30 mm to match the outer diameter of the threaded portion of the flashlight nose. Its purpose is to provide a water-tight seal at the joint between the flashlight body and nose.

To load the o-rings, retract the upper singulation cylinder and insert up to four o-rings as space permits. Make sure the lower cylinder is extended to avoid premature part feeding. Once the o-rings are loaded, extend the upper cylinder.

When feeding an o-ring, the lower cylinder will retract, allowing an o-ring to roll down and fall into place over the positioning cone with the help of the positioning fence. The cylinder will then extend, blocking the feeding channel as the upper cylinder retracts to allow another o-ring to roll into the ready position. Finally, the upper cylinder will extend to ensure only one part is fed during the next cycle. Once this cycle is complete, the robot will pick up the o-ring with a specially designed tool, and the feeder will be in a position to feed another part when another flashlight is assembled.

This feeder design has proven to be fairly reliable for a prototype mechanism. The o-rings will feed correctly approximately nine out of ten times. When they do not feed correctly, it is because of one of two reasons: the o-rings get stuck on the positioning cone, or they roll out of the fence area. A solution to the sticking problem may be to coat the cone in a graphite lubricant or make it out of a material with a smaller coefficient of friction. The fence problem may be fixed by either reducing the angle, and thus the speed, at which the rings slide in, or to increase the height of the fence.

I noticed one other problem with the design. During testing, I found it necessary to glue an o-ring into the bottom of the positioning assembly to provide a flexible surface for the rings to push into as they are picked up. While this was a successful temporary fix, I found that the glued o-ring was showing definite signs of wear due to the action of the tool. This part may require less maintenance if the soft base were made of something more resilient than o-ring rubber. However, a more promising solution would be to make the o-ring picking tool out of different materials. This option will be explained more fully in another section.

## Large O-Ring Tool:


This tool is designed to pick up the large o-ring from its feeding mechanism and place it at the base of the threads on the flashlight's nose. The design consists of three parts: the piston, the outer sleeve, and the inner cylinder. The piston body and outer sleeve are rigidly connected with two small screws, and the inner cylinder is mounted at the end of the piston so it can slide back and forth within the outer sleeve. The piston in the picture is at its fully-retracted state.

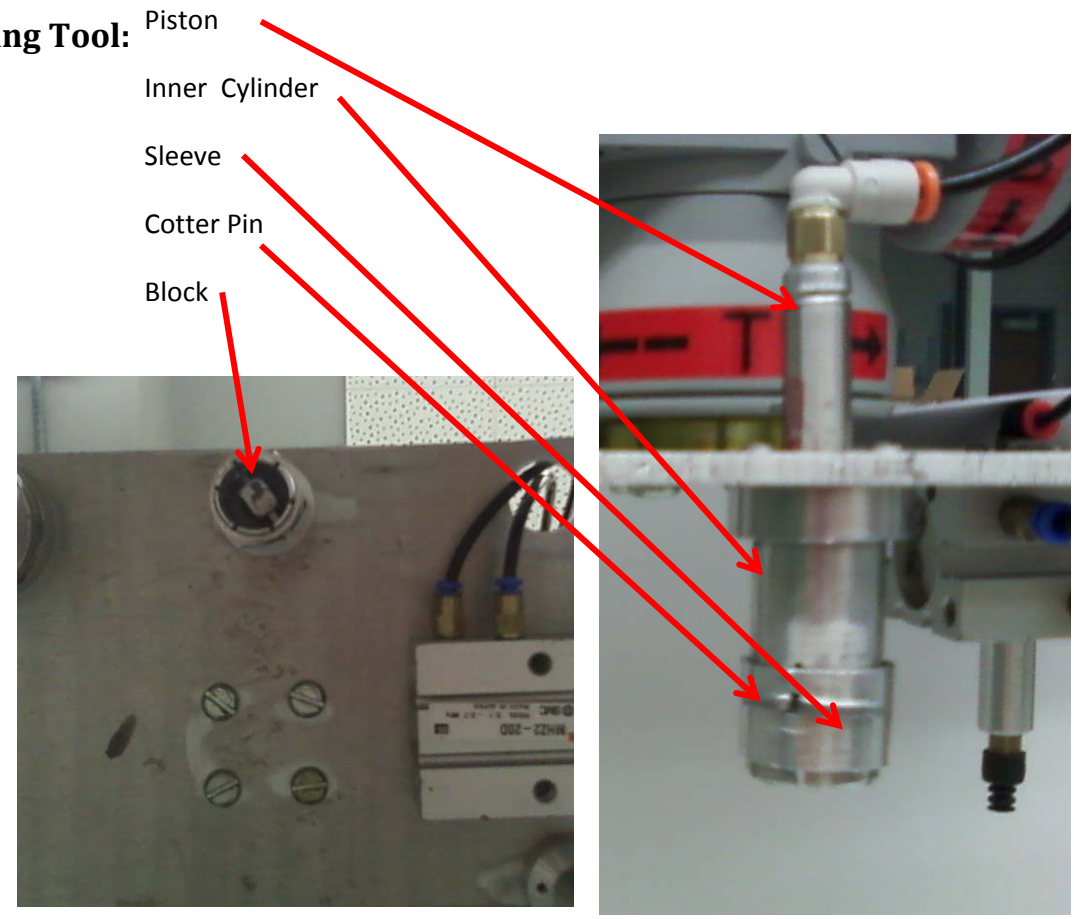
When the program calls for the tool to pick and place a large o-ring, the air to the piston turns on and the inner cylinder extends. The air remains on to provide enough pressure for the inner cylinder to slide over the placement cone on the o-ring feeder and stretch a large o-ring over its outer diameter. Once the o-ring is on the tool, the air turns off and the robot centers the tool over the flashlight's nose. The robot then presses the inner cylinder over the threads on the nose. This pressing continues until the nose forces the piston to retract, and the outer sleeve slides the o-ring off as the inner cylinder retracts with the piston. With the piston retracted, the tool is again in its ready position until the next cycle is called.

The tool worked very well except for one major flaw. The small thickness required of the inner cylinder to fit over the nose threads and slide into the o-ring inner diameter made the aluminum very weak and subject to deformation and fatigue. If the inner cylinder bumped the nose threads and deformed, it would not pick up the next o-ring. This problem could be fixed by using a more resilient material such as a thin plastic.

The G-codes for the tool parts are shown below. The inner cylinder was modified with a manual lathe according to trial-and-error design refinement during testing. The cylinder was

also cut 6 mm deep into six sections to provide more flexibility in sliding over the placement cone and threads.

**Small O-ring Tool:**




The small o-ring tool is designed to pick the small o-ring from its feeder and place it into the front of the flashlight nose so it can provide a watertight seal between the nose and lens. The tool has four main components: a single-acting piston, an inner cylinder, a sleeve, and a transmission block. The inner cylinder is rigidly connected to the piston body, the block is connected to the piston shaft, and the sleeve is connected to the block via a cotter pin. The tool is shown in the above figure in its retracted, ready-to-pick state.

When the program calls for a small o-ring to be placed in the nose, the robot simply drops the tool into the middle of a small o-ring, stretching it over the inner cylinder. With the o-ring on the tool, the robot drops the tool into the center of the nose cone, right above where it is supposed to be placed. The piston then actuates, and the block transmits the motion through the cotter pin into the sleeve, which pushes the o-ring off the inner cylinder. The robot then retracts the tool, and it is ready to be called again for the next cycle.

The tool worked well but had trouble picking up the o-rings. This problem could probably be fixed by editing the end chamfer of the inner cylinder to make a steeper angle onto which an o-ring could slide.

The G-codes for the sleeve and inner cylinder are shown below. The block was simply a block of aluminum small-enough to fit inside the inner cylinder with a hole threaded for the piston shaft and another un-tapped hole for the cotter pin to pass through.

## Body Feeder:

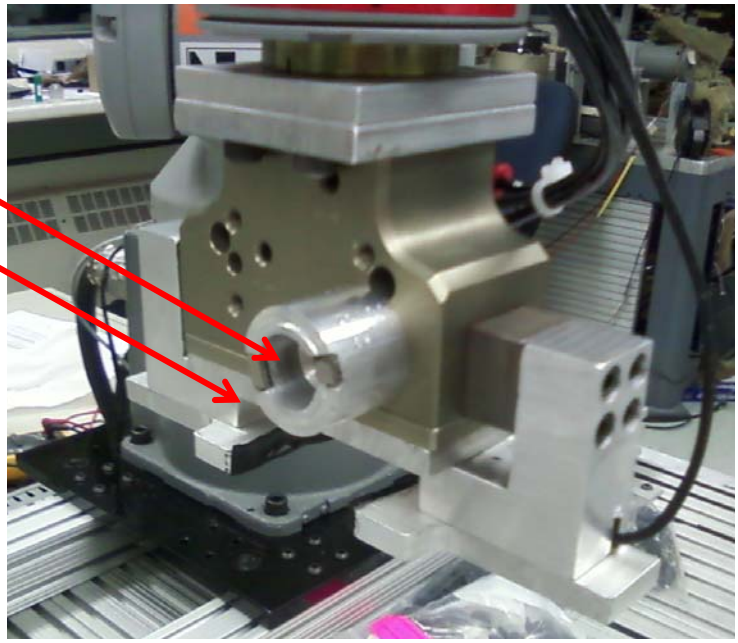
The body feeder's purpose is to ensure that a new flashlight body is in the same spot cycle after cycle. The design consists of a ramp angled in two planes, a thin strip of low-friction plastic, and a pair of angled legs to provide support for the assembly.

To load the feeder, simply line up the flashlight bodies as shown, with the bottom facing out, towards the robot. The feeder ramp can hold up to six bodies. When the program calls for a part, the robot will grip a body from the base and pull it out of the feeder along the body's axis. Once the body is clear, a new body rolls into place, and the feeder is ready for the next cycle.

The feeder was initially built without the plastic strip. But it was found that the aluminum body tended to bind on the feeding ramp and slide at an angle rather than roll controllably. The addition of the plastic removed the binding problem successfully. The angles at which the ramp is mounted were determined by trial and error.

This design's simplicity and passive nature makes it very reliable and successful in operation.

## Snap-Ring Tool:



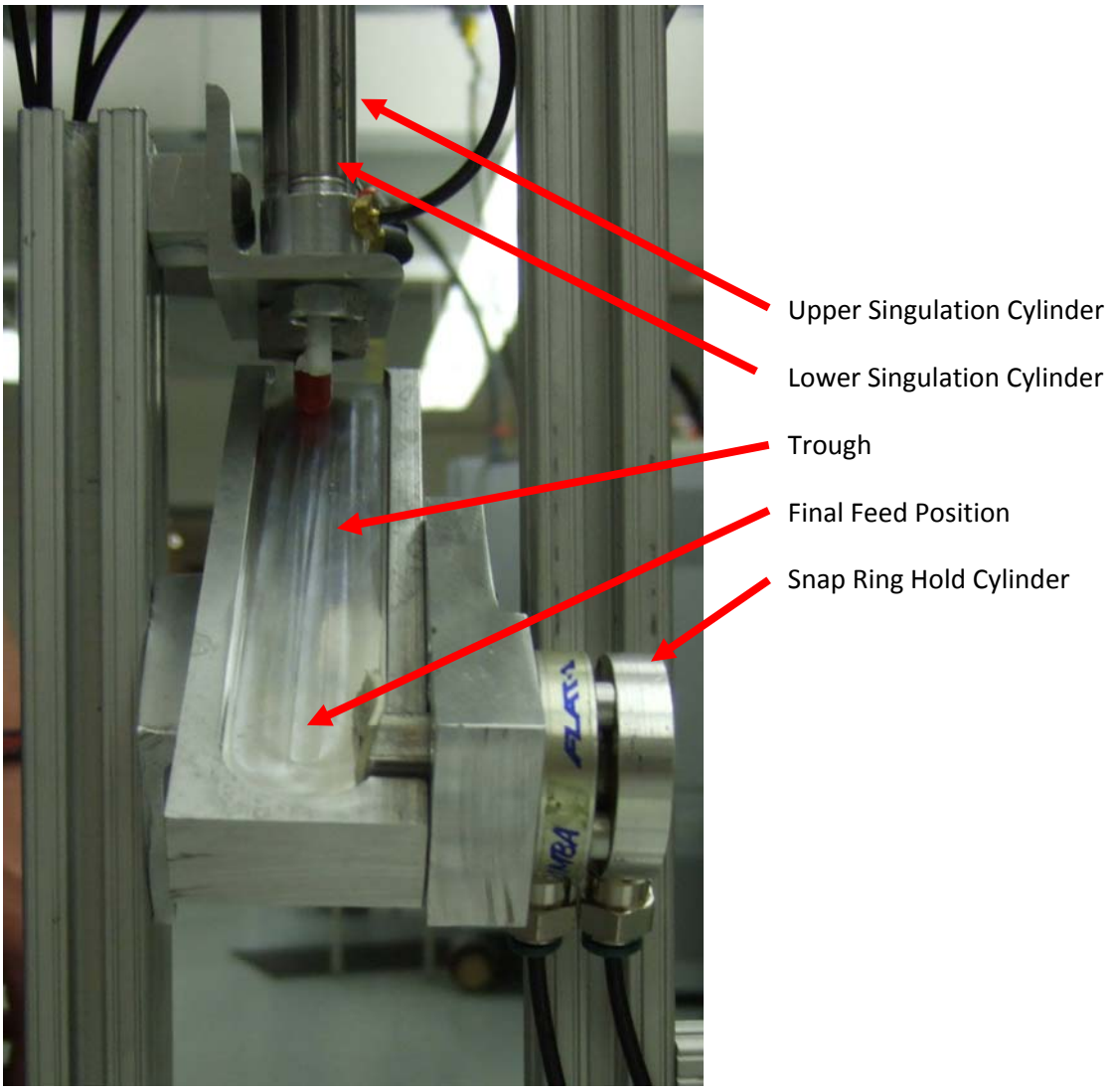

The snap ring tool's purpose is to retrieve a snap ring from its feeing ramp and insert it into the flashlight's nose. It has a very simple design consisting of a specially-shaped cylinder and two small magnets.

When the program calls for a snap-ring, the robot centers the tool where the rings are singulated and fed, and it presses the tool down on the ring. When released by the lower feeder piston, the snap ring is attracted to the face by the magnets in the cylinder face. The ring is centered by the shoulder on the face of the cylinder which matches the inner diameter of the snap ring. Once the ring is loaded, the robot centers it over the nose cone of the flashlight and presses it into place. The friction fit in the flashlight head keeps the snap-ring in place as the robot pulls the tool away.

There were issues with the rings tending to jump at the tool too early and land off-center, resulting in a failed part insertion. The shoulder is already as deep as it can be without causing clearance issues with the flashlight's LED module and heat-sink, so another way of fixing this problem would be changing the magnets. Weaker magnets would allow the tool to get closer to the ring before the ring is attracted to the face. With less "free-flying" space, the rings would be more prone to centering themselves over the shoulder of the tool.

The G-code for the snap-ring tool is shown below.

## Snap ring feeder:




The snap ring is a metallic ring with an outside diameter slightly larger than inside diameter of the nose cone. When pressed into place just above the heat sink, the ring sticks in place because it's pressing against nose cone. This snap ring holds the heat sink in place.

To load the snap ring feeder, place a snap ring horizontally at the top of the slide, and retract the near (relative to the top of the tray) singulation cylinder. The lower singulation cylinder should be fully extended. After inserting the first snap ring, extend the upper singulation cylinder and insert another snap ring.

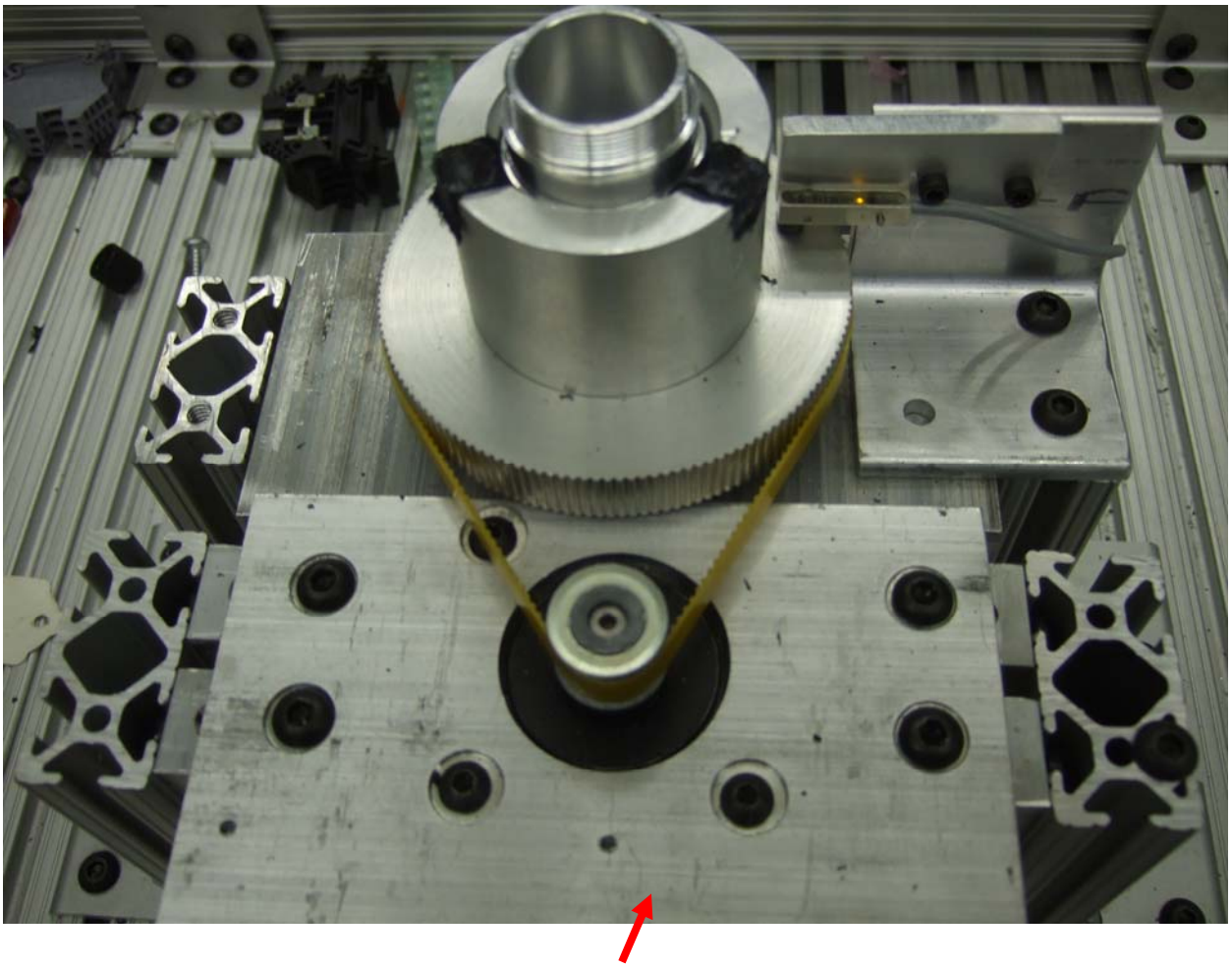
During operation, the cylinder at the bottom end of the feeder (snap ring hold cylinder) should be retracted when no ring is present. The lower singulation cylinder will retract, allowing the first snap ring to slide to the bottom. The lower singulation cylinder will then extend so the upper cylinder can retract. This will allow the second snap ring to become ready.

After the feeding cycle has completed, the snap ring hold cylinder will extend, locking the snap ring in place. The robot will come to pick it up with a magnet. The snap ring hold

cylinder holds the snap ring so the robot can correctly align with the center of the snap ring. This ensures accurate placement in the nose cone. When the robot is contacting the snap ring, the snap ring hold cylinder retracts, which releases the snap ring. The robot then takes it to the assembly area.

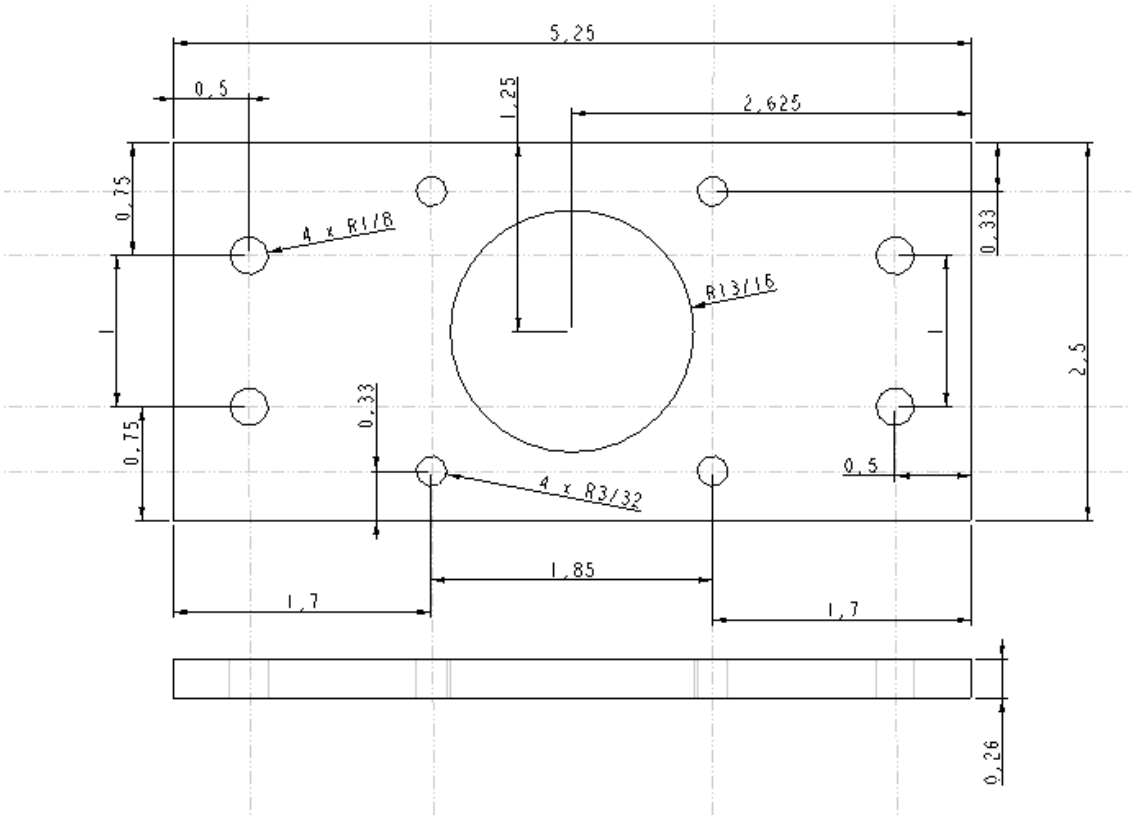
The snap ring feeder doesn't typically have a problem with jamming. The real problems are in the singulation and sliding processes. The snap rings are made of a spring-like material. Occasionally, after sliding down the feeder, the ring will bounce out of the feeder. The trough was milled deeper, which helped the problem. A deeper cut should solve the problem. Also, the snap rings have a tendency to catch on the threads of the lower singulation cylinder. When the cylinder retracts, they fly out of the feeder. Also, to help with the singulation process, the singulation cylinders should be spaced about a quarter inch farther apart. Finally, because the snap rings are incredibly thin, they have a tendency to slide over each other, which defeats the purpose of singulation.

## Assembly motor bracket



Assembly motor bracket

In order to screw the threads of the flashlight body onto the nosecone, the nose cone is rotated relative to the body. The nose cone is rotated by a belt drive from a motor, located to the side. The bracket for this motor was custom machined so the bolt holes would correctly align. All holes were partially countersunk so the belt and other machinery could operate inhibited. The assembly motor is bolted to the underside of the bracket. The bracket is, in turn, mounted several inches above the table.




G03X2.0778Y1.305I.4886J-.2525
G01X3.1722
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G01X2.0938
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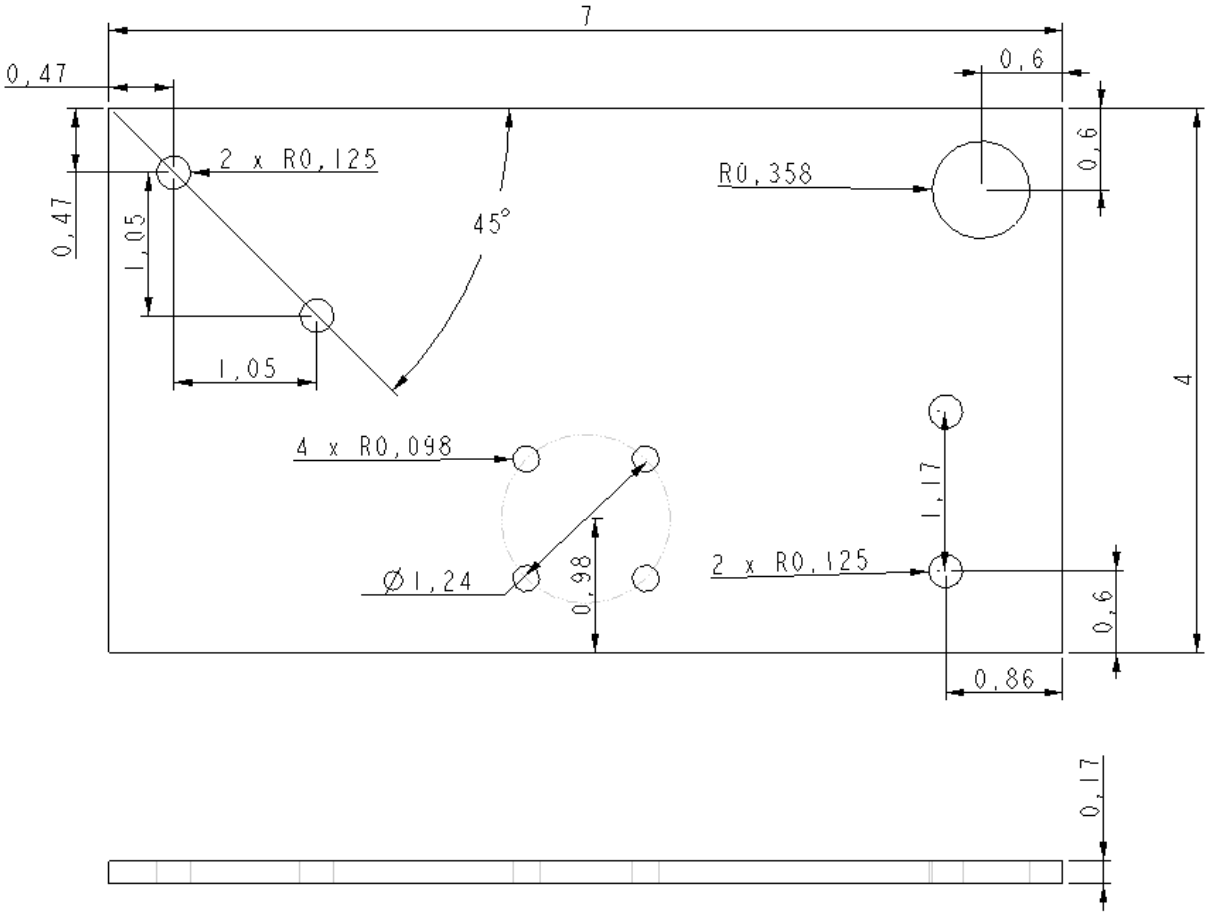
G01X2.5085
G03X2.5085Y.7125I.1165J.5375
G01Z.1
N0020T3M06
S1400M03
G00X1.7Y.325
G43Z.1H03M09
G81X.5Y.75Z-.06R.1F5.
Y1.75
X1.7Y2.175
X3.55
X4.75Y1.75
Y.75
X3.55Y.325
G80
M30
%

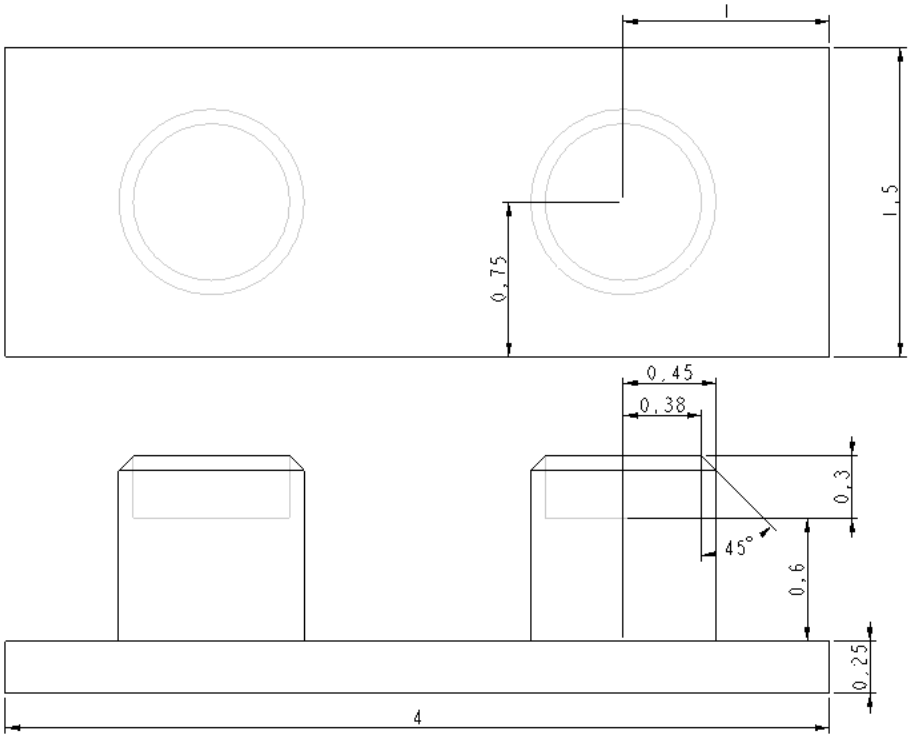
## Robot Head Bracket



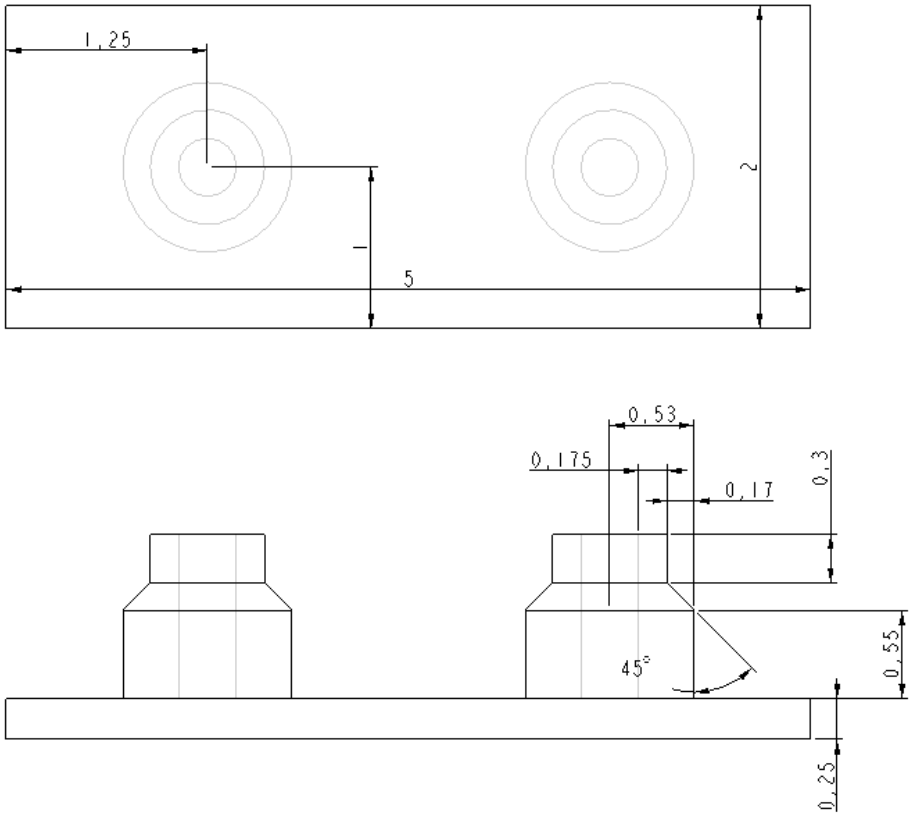

This bracket mounts to the bottom of the left robot. It provides a location to mount several of the part grabbing mechanisms. Screws are put through the four holes in the bottom center of the top view to connect the plate to the robot head. The holes in the top left connect the large o-ring cylinder to the bracket. The two small holes on the right side connect the magnetic ring-grabbing cylinder to the plate. Finally, the large hole in the top right was originally milled for the small o-ring cylinder. However, the small o-ring cylinder dimensions changed and the cylinder had to be moved. A new hole was drilled by hand in the top center of the plate.

## Part Trays

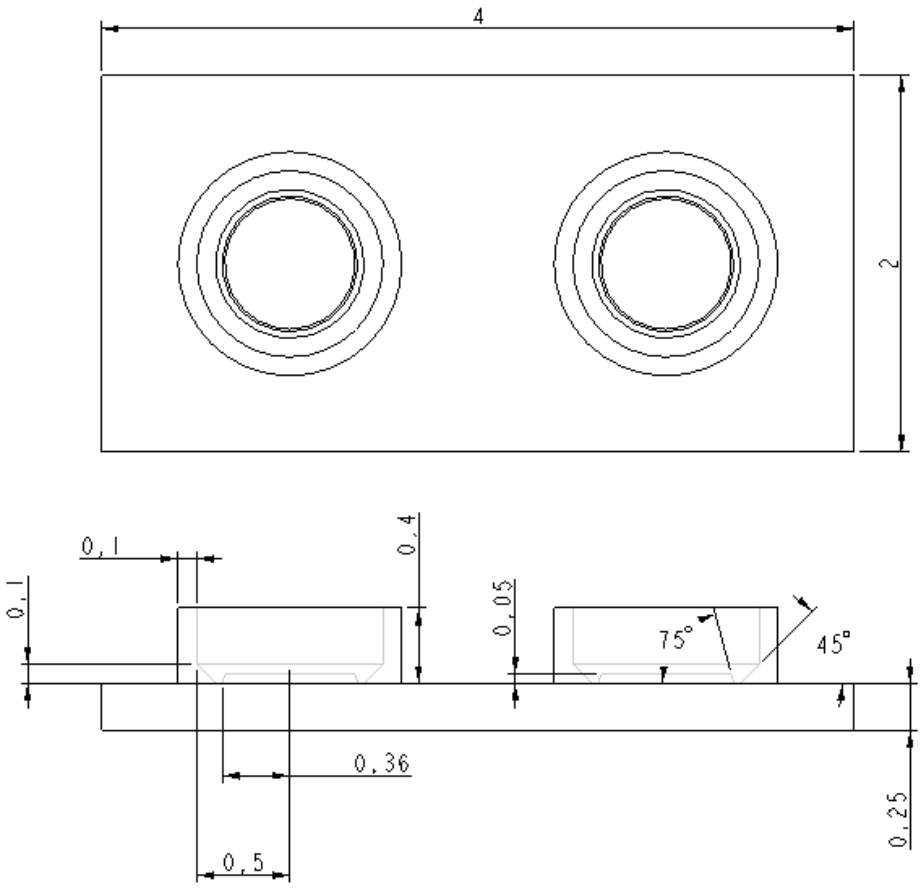
Early in the quarter, the class was divided into three teams. The robotics teams were told that singulating feeders weren't required. Instead, a set of trays could hold some of the parts. Trays were modeled and printed to hold the battery, flashlight body, nose cone, and heat sink modules. Below are drawings for the parts.



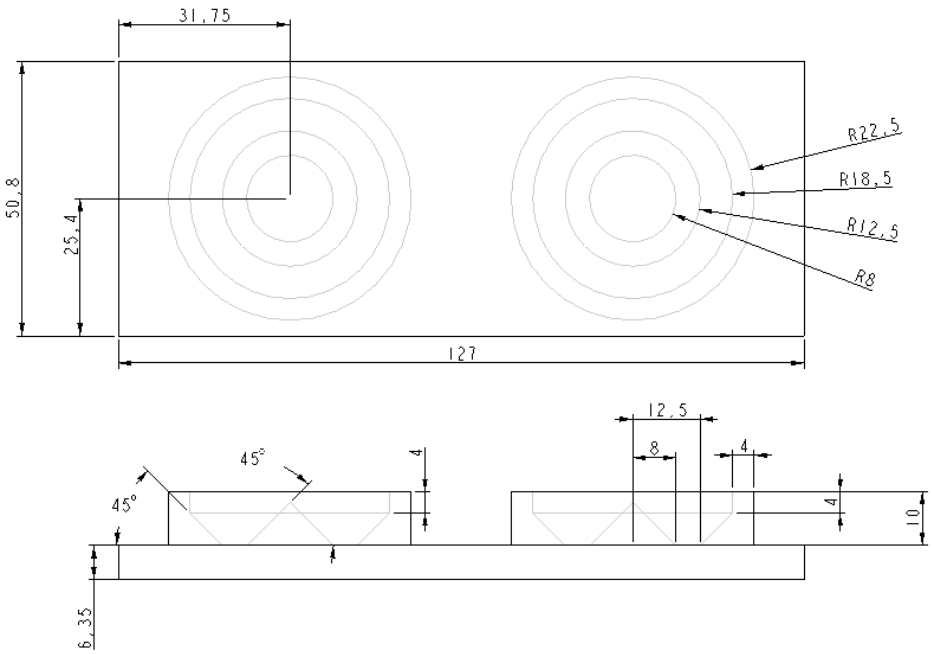

Battery tray – units in inches




Flashlight body tray – units in inches

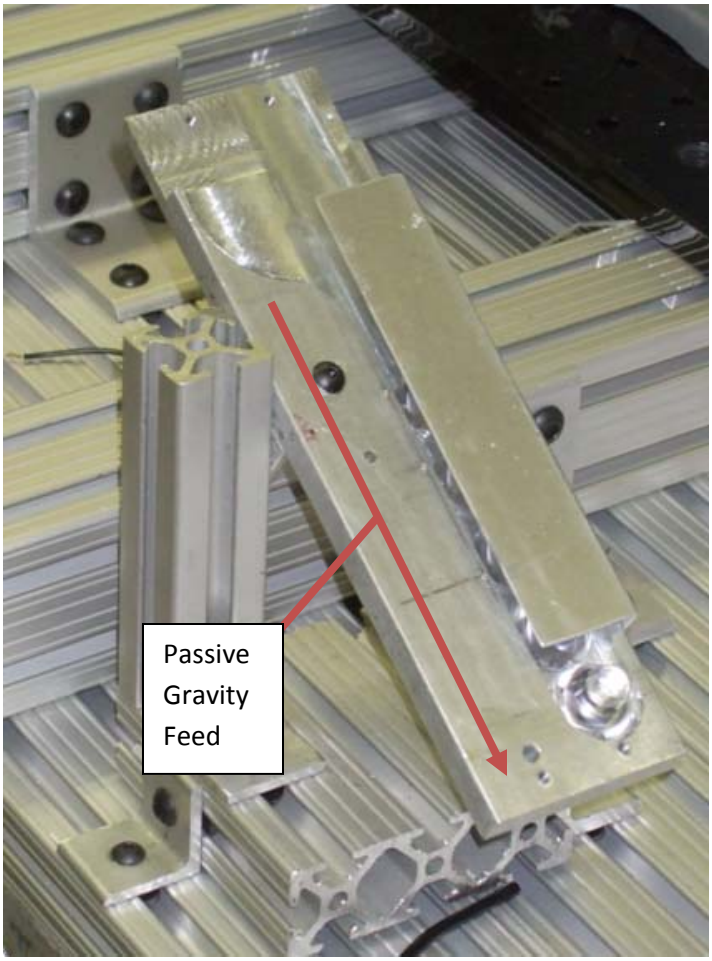



Heat sink tray – units in inches



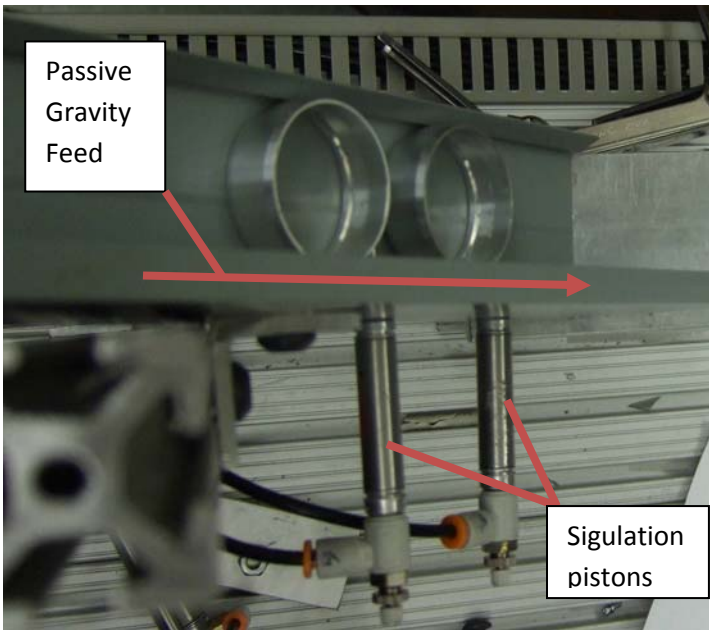

Nose cone tray – units in inches

## Lens Feeder




The lens is gravity fed, with flat side down. It has a cover to avoid bunching the lens up or having them fall out. There is a stop at the bottom.

## Magnet.. Ring Feeder



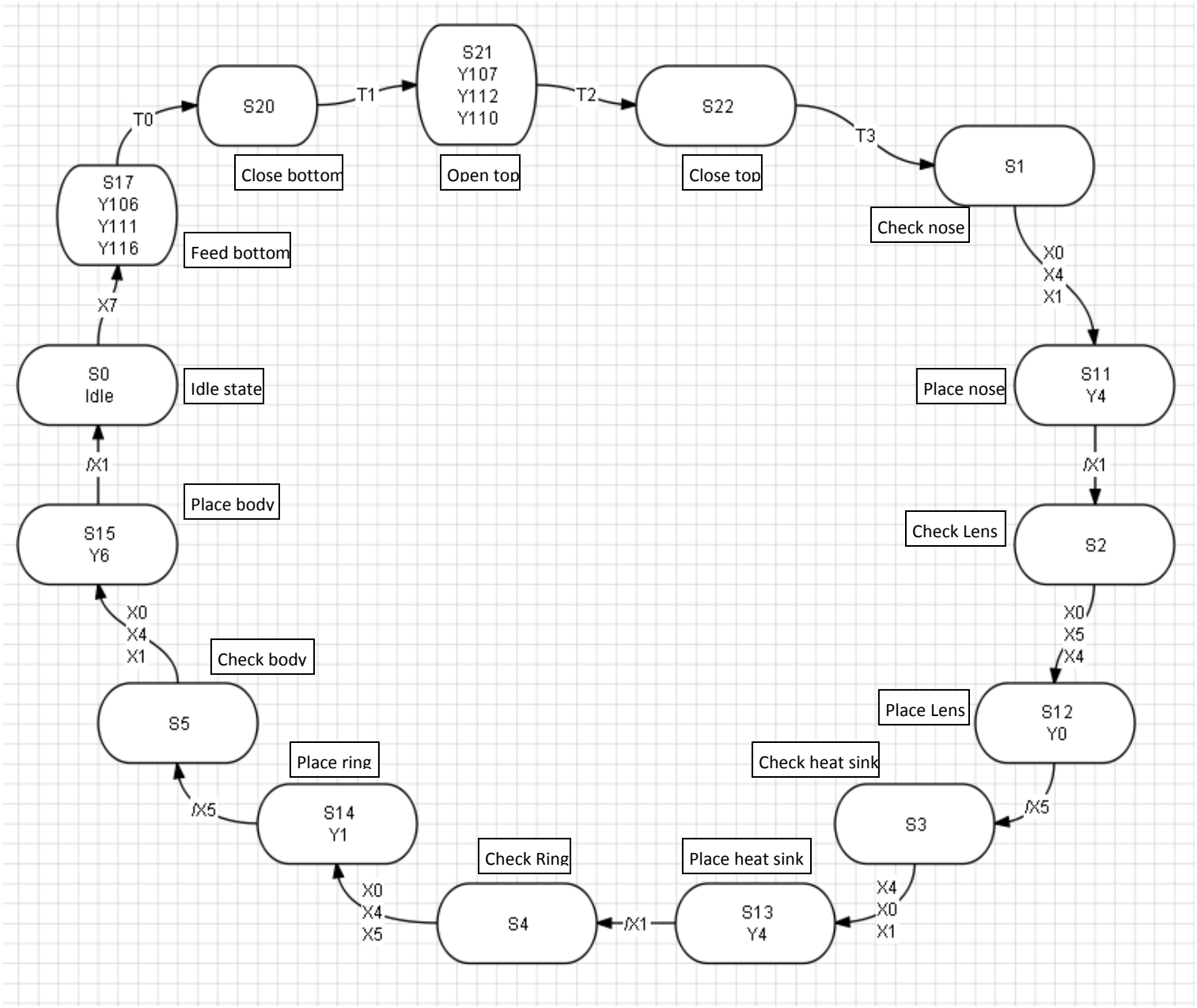

The metal rings are gravity fed, with pistons to singulate them. It drops out onto a flat metal plate where the grippers on the robot pick them up.

## Assembly Process:

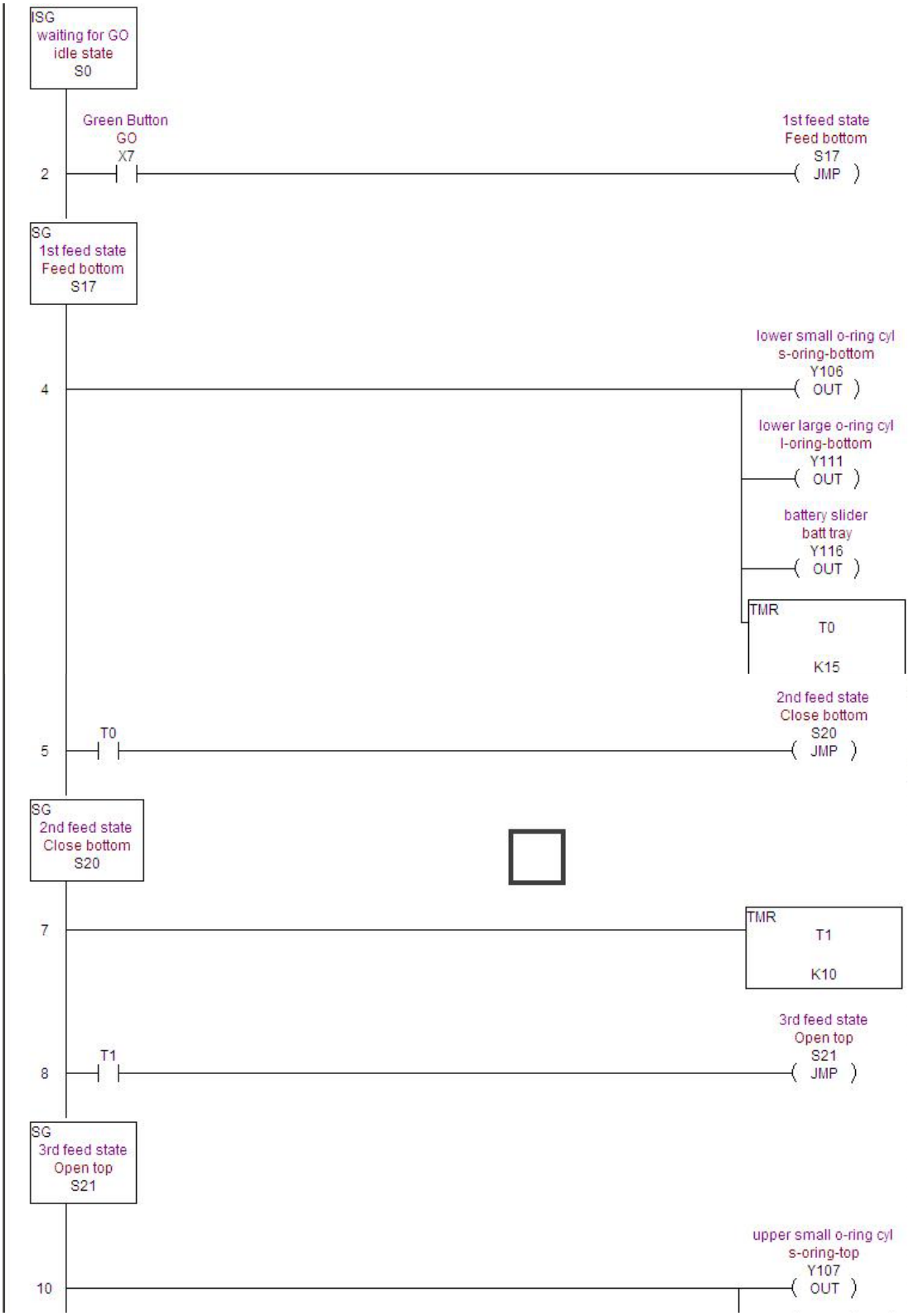
When the start cycle button is pressed, every active feeding and singulation mechanism except for the magnet ring feeder actuates and the parts are set in their ready positions.

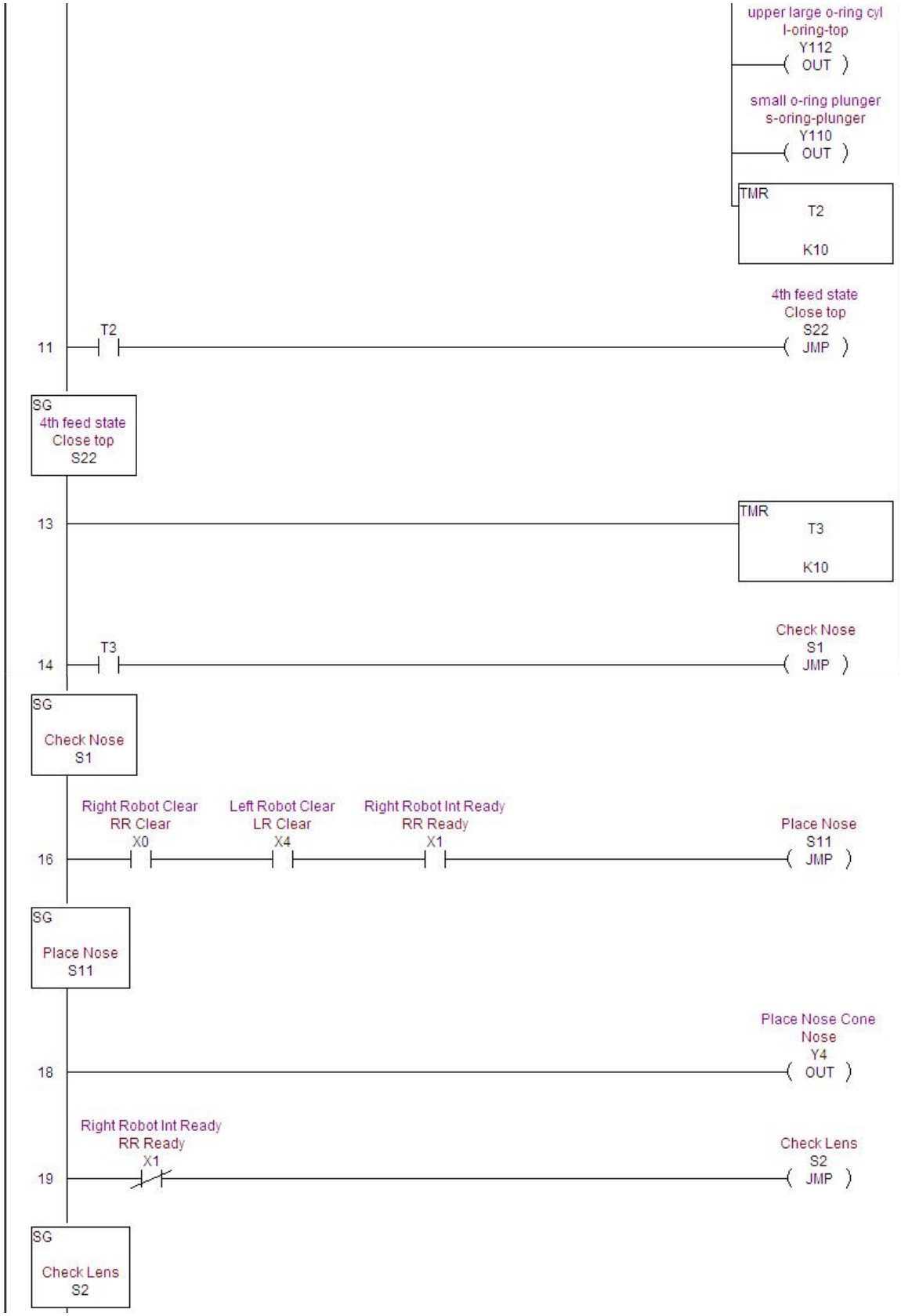
| Robot 1 | Robot 2 |
| --- | --- |
| Picks up lens with vacuum tool and small o-ring with small o-ring tool. | Uses gripper to pick up nose cone and presses it into the central assembly platform. |
| Places small o-ring in nose cone, followed by the lens. | Picks up heat-sink with gripper and snap ring with snap ring tool. |
| Moves to magnet ring feeder. Magnet ring feeder actuates, and the robot catches the magnet ring with its gripper. Moves to large o-ring feeder and picks up o-ring with tool. | Places heat-sink into nose cone and presses snap-ring into place. |
| Places big o-ring on nose cone and sets magnet ring into place over threads. | Retrieves body and collects battery from feeder. |
| Returns to home position and waits for next cycle. | Sets body and battery on threads of nose cone while the assembly platform rotates. Once rotation is finished, robot moves completed assembly to finished rack and then moves to home position and waits for next cycle |

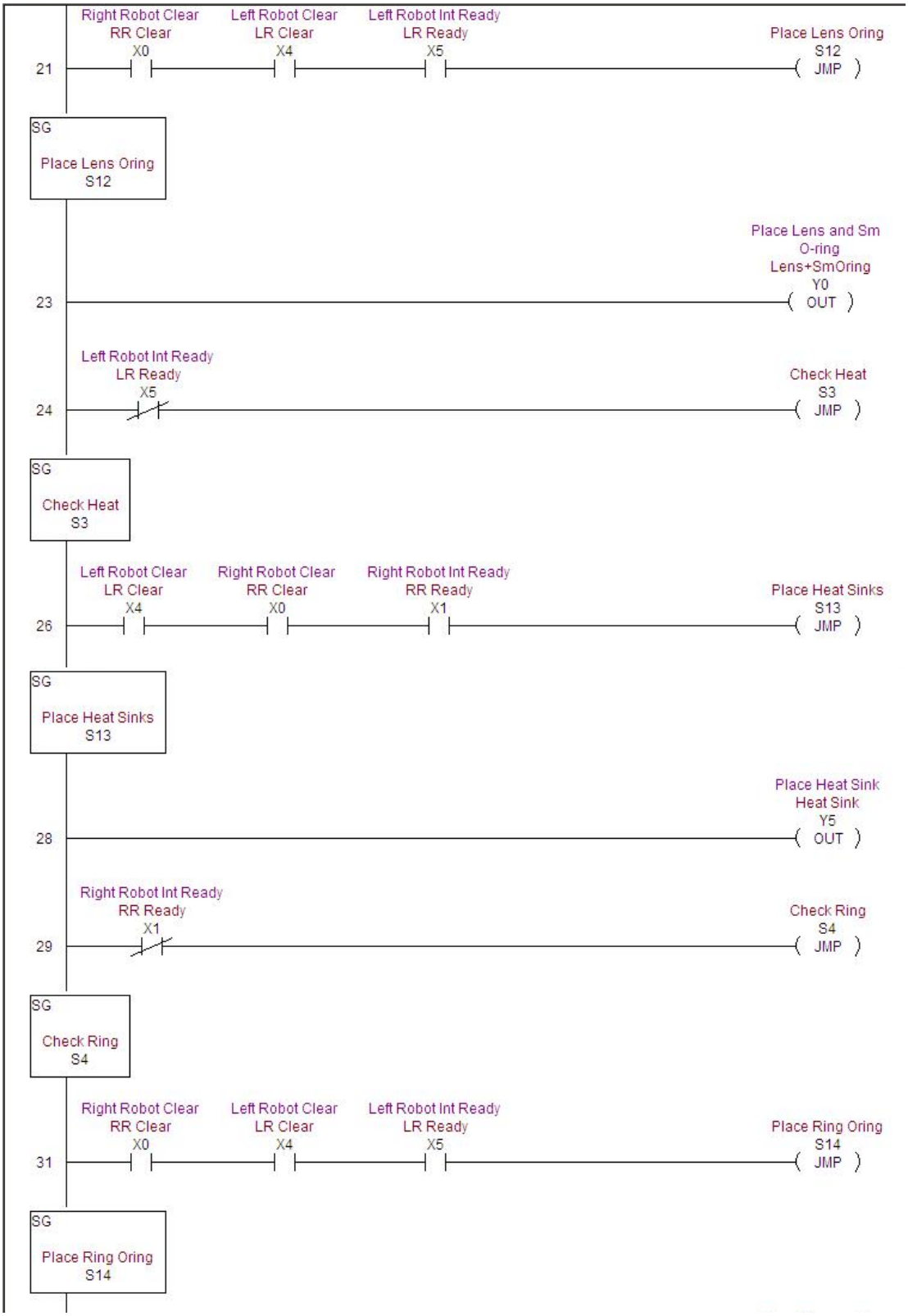
## State Flow Chart

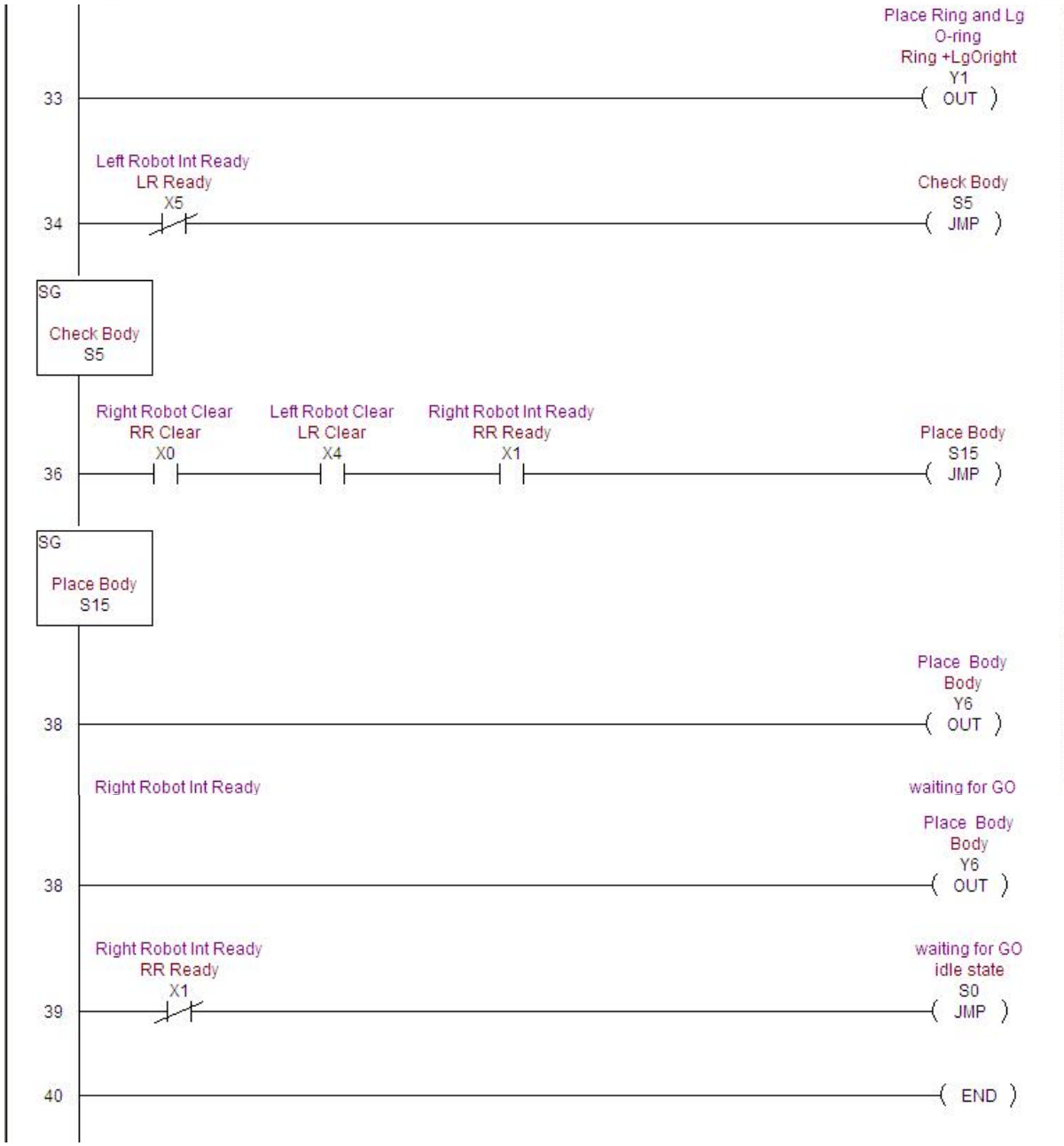


## State Ladder Logic

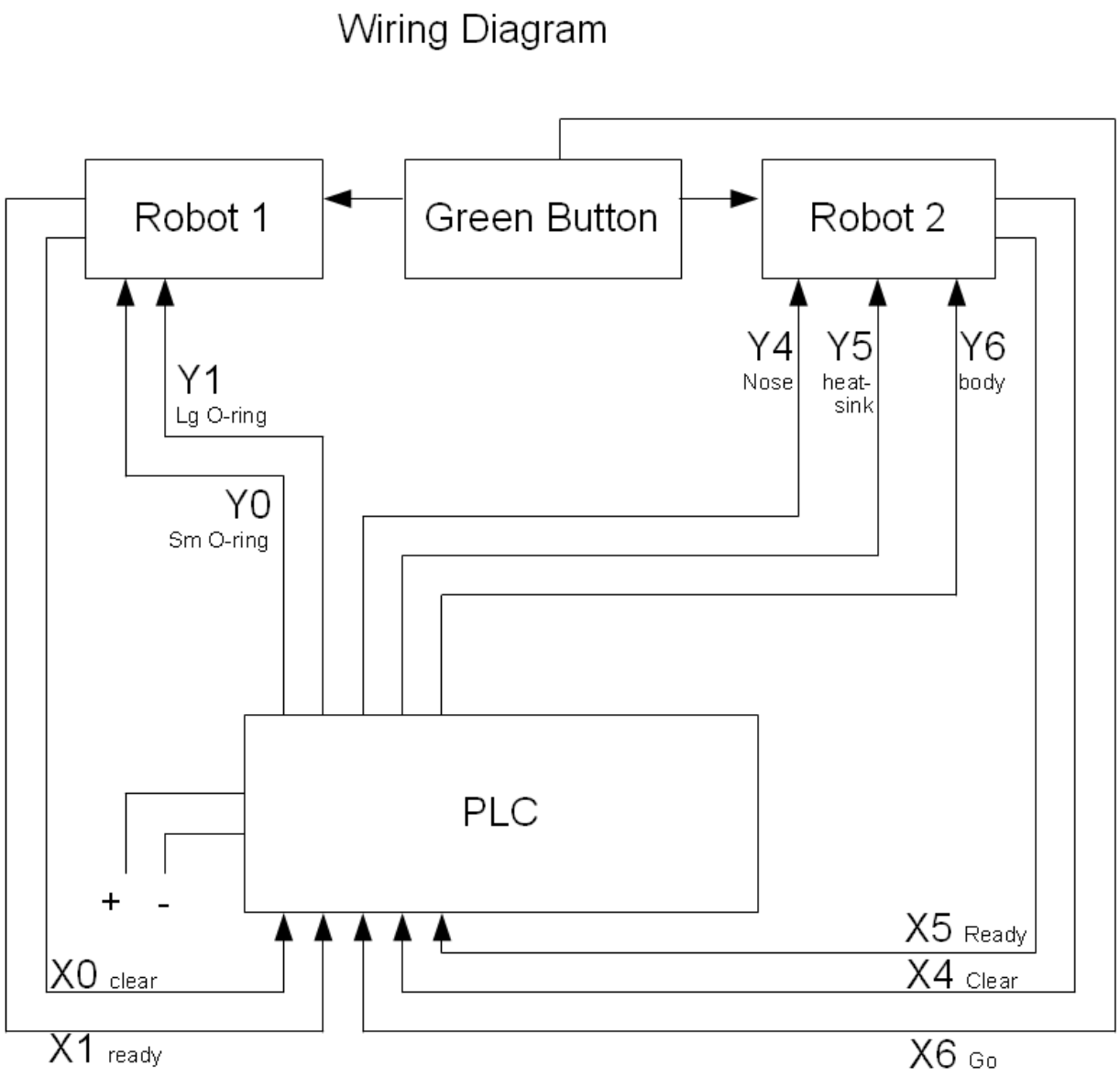


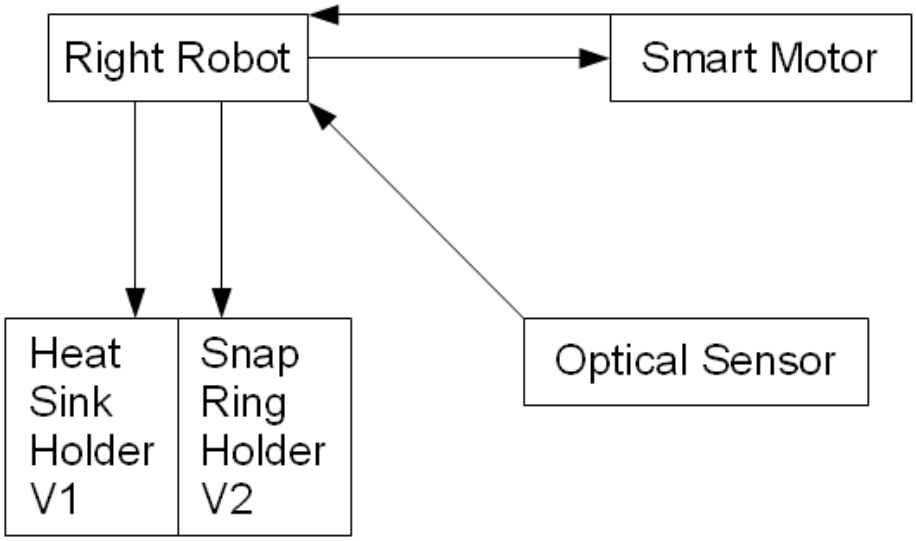

upper large o-ring cyl
l-oring-top
Y112
OUT
small o-ring plunger
s-oring-plunger
Y110
OUT
TMR
T2
K10
4th feed state
Close top
S22
JMP
11
T2
SG
4th feed state
Close top
S22
13
TMR
T3
K10
Check Nose
S1
JMP
14
T3
SG
Check Nose
S1
Right Robot Clear
RR Clear
X0
Left Robot Clear
LR Clear
X4
Right Robot Int Ready
RR Ready
X1
Place Nose
S11
JMP
16
SG
Place Nose
S11
Place Nose Cone
Nose
Y4
OUT
18
Right Robot Int Ready
RR Ready
X1
Check Lens
S2
JMP
19
SG
Check Lens
S2

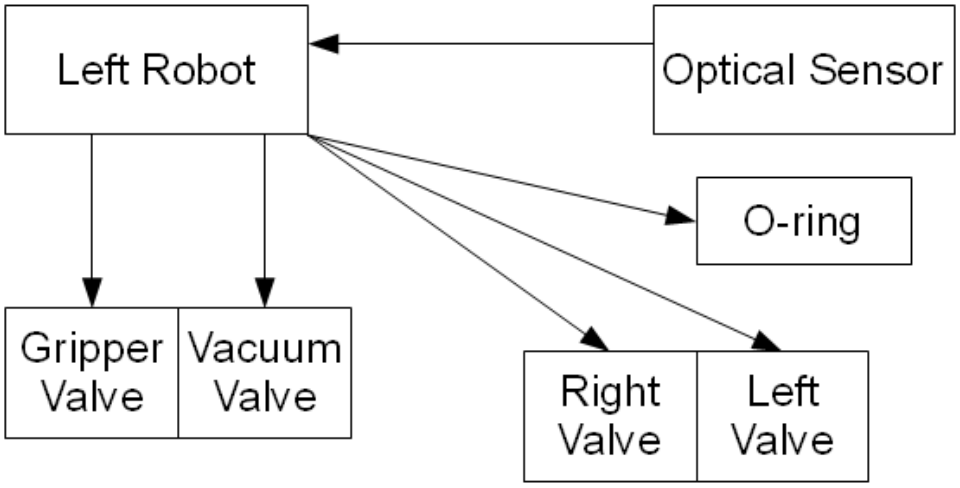

Right Robot Clear
RR Clear
X0
Left Robot Clear
LR Clear
X4
Left Robot Int Ready
LR Ready
X5
Place Lens Oring
S12
JMP
21
SG
Place Lens Oring
S12
Place Lens and Sm
O-ring
Lens+SmOring
Y0
OUT
23
Left Robot Int Ready
LR Ready
X5
Check Heat
S3
JMP
24
SG
Check Heat
S3
Left Robot Clear
LR Clear
X4
Right Robot Clear
RR Clear
X0
Right Robot Int Ready
RR Ready
X1
Place Heat Sinks
S13
JMP
26
SG
Place Heat Sinks
S13
Place Heat Sink
Heat Sink
Y5
OUT
28
Right Robot Int Ready
RR Ready
X1
Check Ring
S4
JMP
29
SG
Check Ring
S4
Right Robot Clear
RR Clear
X0
Left Robot Clear
LR Clear
X4
Left Robot Int Ready
LR Ready
X5
Place Ring Oring
S14
JMP
31
SG
Place Ring Oring
S14


Place Ring and Lg O-ring
Ring +LgOright
Y1
OUT
33
Left Robot Int Ready
LR Ready
X5
34
Check Body
S5
JMP
SG
Check Body
S5
Right Robot Clear
RR Clear
X0
Left Robot Clear
LR Clear
X4
Right Robot Int Ready
RR Ready
X1
36
Place Body
S15
JMP
SG
Place Body
S15
Place Body
Body
Y6
OUT
38
Right Robot Int Ready
waiting for GO
Place Body
Body
Y6
OUT
38
Right Robot Int Ready
RR Ready
X1
39
waiting for GO
idle state
S0
JMP
40
END

## Wiring Diagrams




Right Robot
Smart Motor
Heat Sink Holder V1
Snap Ring Holder V2
Optical Sensor

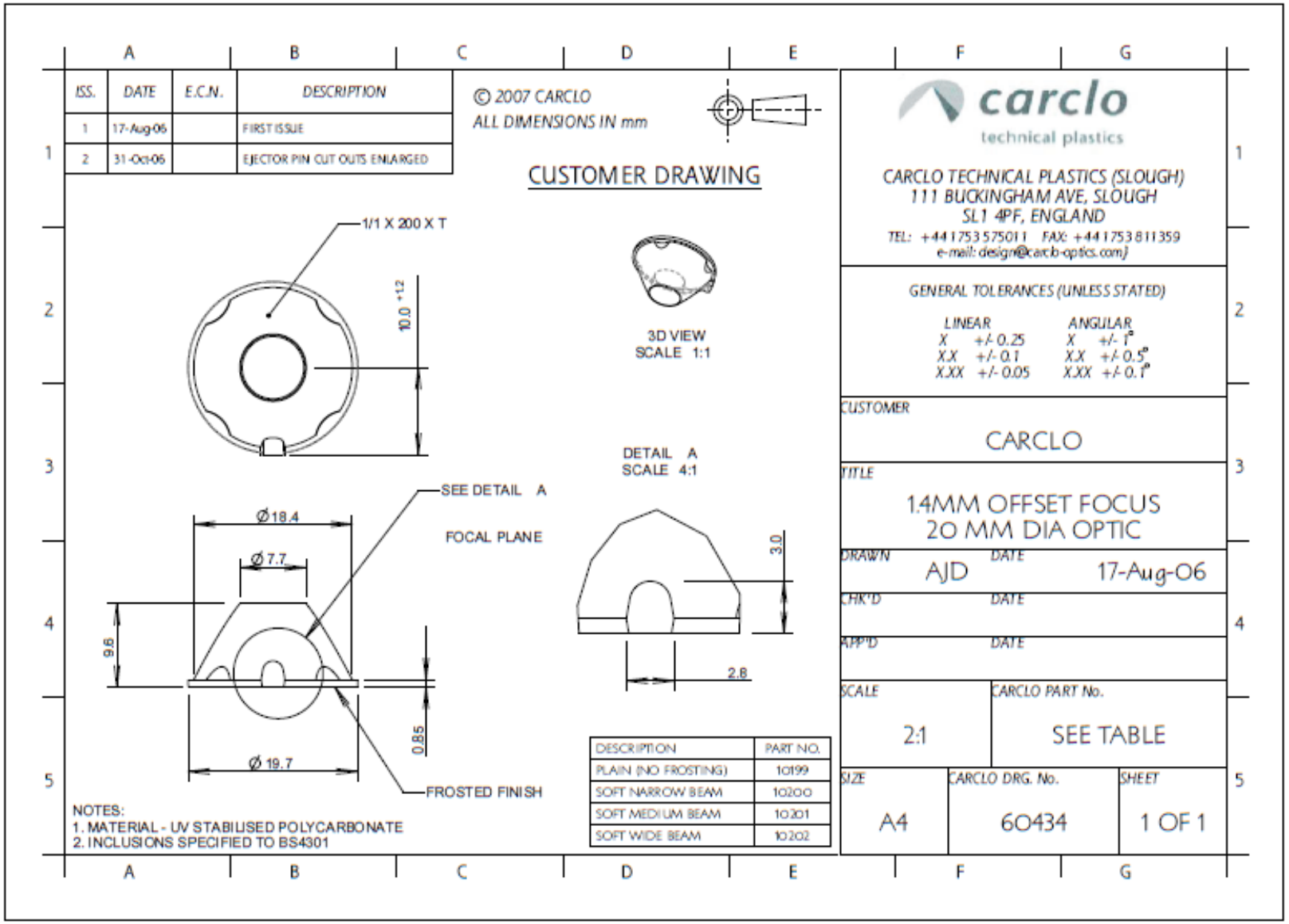

Left Robot
Optical Sensor
O-ring
Gripper Valve
Vacuum Valve
Right Valve
Left Valve

## Smart Motor Program

```
UAO
UBI
UCI
ZS
C1
UA=1
WHILE UBI==1
V=32212*20
A=80
D=50
G
LOOP
UA=0
WHILE UCI==1 LOOP
UA=1
V=32212*5
A=150
D=-13000*3
G
TWAIT
WHILE UCI==0 LOOP
UA=0
WHILE UCI==1 LOOP
UA=1
V=32212*5
A=150
D=-13000*3
G
TWAIT
WHILE UCI==0 LOOP
GOTO1
END
```

## Flashlight Bill of Materials :

| | | |
|---|---|---|
| Lens | – | Provided by instructor, spec sheet attached |
| Battery | – | Provided by instructor, spec sheet attached |
| Nose Cone | – | Machined from bar stock, G-code attached |
| Body | – | Machined from bar stock, G-code attached |
| Magnet Ring | – | Machined from bar stock, G-code attached |
| Heat Sink | – | Machined from bar stock, circuitry and LED provided by instructor, spec sheet attached |
| Large O-ring | – | Provides seal between nose cone and body |
| Small O-ring | – | Provides seal around lens |


ISS. DATE E.C.N. DESCRIPTION
1 17-Aug-06 FIRST ISSUE
2 31-Oct-06 EJECTOR PIN CUT OUTS ENLARGED
© 2007 CARCLO
ALL DIMENSIONS IN mm
CUSTOMER DRAWING
carclo
technical plastics
CARCLO TECHNICAL PLASTICS (SLOUGH)
111 BUCKINGHAM AVE, SLOUGH
SL1 4PF, ENGLAND
TEL: +44 1753 575011 FAX: +44 1753 811359
e-mail: design@carclo-optics.com
GENERAL TOLERANCES (UNLESS STATED)
LINEAR
X +/- 0.25
X.X +/- 0.1
X.XX +/- 0.05
ANGULAR
X +/- 1°
X.X +/- 0.5°
X.XX +/- 0.1°
1/1 X 200 X T
10.0 +1.2
3D VIEW
SCALE 1:1
DETAIL A
SCALE 4:1
SEE DETAIL A
FOCAL PLANE
Ø18.4
Ø7.7
9.6
0.85
Ø19.7
FROSTED FINISH
3.0
2.8
CUSTOMER
CARCLO
TITLE
1.4MM OFFSET FOCUS
20 MM DIA OPTIC
DRAWN AJD DATE 17-Aug-06
CHK'D DATE
APP'D DATE
SCALE 2:1
CARCLO PART No. SEE TABLE
SIZE A4
CARCLO DRG. No. 60434
SHEET 1 OF 1
DESCRIPTION PART NO.
PLAIN (NO FROSTING) 10199
SOFT NARROW BEAM 10200
SOFT MEDIUM BEAM 10201
SOFT WIDE BEAM 10202
NOTES:
1. MATERIAL - UV STABILISED POLYCARBONATE
2. INCLUSIONS SPECIFIED TO BS4301

# Batteryspace.com

# LFP-18650-1200 battery

Drawing

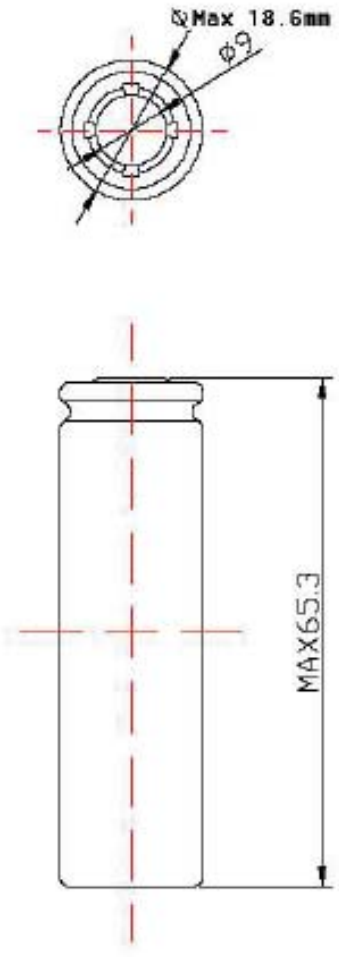
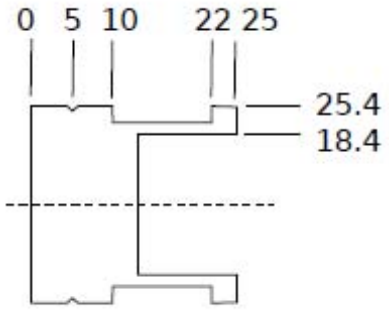



fig.1

# LED Module - 2010 Model



**Programs**

**Left Robot Job: Master**

```
/JOB
//NAME MASTER
//POS
///NPOS 0,0,0,15,0,0
///TOOL 0
///POSTYPE PULSE
///PULSE
P00000=0,33878,-67798,0,-13063,0
P00001=-14939,89558,-24761,-374,-3187,5946
P00002=-14307,91956,-17114,-4102,-7577,8355
P00003=-14439,97233,-14849,-5238,-5966,9135
P00004=89499,73979,-10274,-312,-30454,-34203
P00005=89409,81225,-8911,-347,-27083,-34135
P00006=-62773,91739,-22678,29709,-38043,6720
P00007=-64202,94100,-22927,30302,-36748,5816
P00008=72827,67240,-11611,-240,-33577,-27853
P00009=72827,74660,-10871,-268,-29631,-27832
P00014=-58801,78729,-35830,1527,-9022,-30012
P00015=-54889,83906,-28445,1210,-11258,-31313
P00016=75707,66926,-31660,-136,-19400,-36740
P00017=75707,71349,-30787,-150,-17361,-36729
P00018=79019,55928,-30093,-736,-29026,-53291
//INST
///DATE 2010/06/07 12:50
///ATTR SC,RW
///GROUP1 RB1
NOP
*LABEL
WAIT IN#(4)=ON
MOVL P000 V=300.0
DOUT OT#(7) ON
DOUT OT#(1) OFF
DOUT OT#(2) OFF
DOUT OT#(3) OFF
MOVL P006 V=300.0
MOVL P007 V=25.0
DOUT OT#(1) ON
TIMER T=0.50
MOVL P006 V=25.0
MOVL P000 V=300.0
MOVL P001 V=300.0
MOVL P002 V=25.0
MOVL P003 V=10.0
TIMER T=0.50
MOVL P002 V=10.0
MOVL P001 V=25.0
MOVL P000 V=300.0
DOUT OT#(8) ON
WAIT IN#(2)=ON
DOUT OT#(8) OFF
DOUT OT#(7) OFF
MOVL P004 V=300.0
MOVL P005 V=25.0
DOUT OT#(3) ON
TIMER T=0.50
DOUT OT#(3) OFF
MOVL P004 V=25.0
MOVL P018 V=50.0
MOVL P008 V=50.0
MOVL P009 V=25.0
TIMER T=0.25
DOUT OT#(1) OFF
MOVL P008 V=25.0
MOVL P000 V=300.0
DOUT OT#(7) ON
MOVL P014 V=300.0
MOVL P015 V=25.0
DOUT OT#(4) ON
TIMER T=0.50
DOUT OT#(4) OFF
DOUT OT#(5) ON
TIMER T=2.00
DOUT OT#(5) OFF
WAIT IN#(1)=OFF
DOUT OT#(2) ON
MOVL P014 V=25.0
MOVL P000 V=300.0
CALL JOB:LG_ORING
DOUT OT#(8) ON
WAIT IN#(3)=ON
DOUT OT#(8) OFF
DOUT OT#(7) OFF
MOVL P016 V=300.0
MOVL P017 V=25.0
TIMER T=2.00
DOUT OT#(2) OFF
MOVL P016 V=25.0
MOVL P000 V=300.0
DOUT OT#(7) ON
JUMP *LABEL
END
```

**Left Robot Job: LG_ORING**

```
/JOB
//NAME LG_ORING
//POS
///NPOS 0,0,0,7,0,0
///TOOL 0
///POSTYPE PULSE
///PULSE
P00000=0,33878,-67798,0,-13063,0
P00019=31854,97232,-5465,-260,-20298,-24940
P00020=23948,85765,-27208,858,-11163,17646
P00021=86951,68394,-22608,375,-24954,18055
P00022=87039,61669,-23151,209,-28602,18274
P00023=31854,93243,-7094,-246,-21528,-24950
P00024=23717,88587,-26168,940,-10222,17717
//INST
///DATE 2010/06/07 13:07
///ATTR SC,RW
///GROUP1 RB1
NOP
MOVL P000 V=200.0
DOUT OT#(3) ON
TOOLON
MOVL P020 V=200.0
MOVL P024 V=25.0
TIMER T=1.00
MOVL P019 V=25.0
TIMER T=0.50
MOVL P023 V=25.0
DOUT OT#(3) OFF
MOVL P022 V=150.0
MOVL P021 V=25.0
MOVL P022 V=25.0
TOOLOF
MOVL P000 V=200.0
END
```

**Right Robot Code Job: Flashlight**

```
/JOB
//NAME FLASHLIGHT
//POS
///NPOS 0,0,0,28,0,0
///TOOL 0
///POSTYPE PULSE
///PULSE
P00000=-62201,28183,-38121,0,-37804,127035
P00001=-40196,69652,-48474,-127557,-
17327,147323
P00002=-37969,83979,-40381,-133639,-
19478,150492
P00003=-82563,67744,-3866,0,-38751,83310
P00004=-82666,72461,-4247,-550,-35375,32027
P00005=-60448,78738,-36985,-115009,-
21113,146502
P00006=-57995,89095,-30063,-119026,-
21719,148241
P00007=-82387,67113,-4192,0,-38908,31647
P00008=-82387,70830,-4232,0,-36631,31641
P00009=19744,95111,-38429,150630,-71493,-8527
P00010=18481,97373,-32443,151221,-68617,-8046
P00011=18697,96918,-32749,151090,-68543,-8032
P00012=23705,90437,-52129,148552,-78223,-9913
P00013=26084,53788,-38199,108,-22336,93131
P00014=26085,73959,-34917,187,-12530,93073
P00015=-82408,60102,-2964,0,-44009,134800
P00016=-82408,62205,-3395,0,-42426,134797
P00017=-82406,54812,-1136,0,-48340,134790
P00018=-48872,92686,44003,90,-58203,121891
P00019=-48871,103196,43694,97,-51624,121883
P00020=-82387,72362,-4170,0,-35752,31644
P00021=-79802,68256,-11151,0,-33176,30654
P00022=-52948,110687,56351,82,-56274,123452
P00023=16421,78515,-56871,82301,112497,58365
P00024=21739,89178,-51983,80958,112983,60520
P00025=-80344,79285,-31214,814,69157,51335
P00026=-80121,82735,-29946,673,70270,51353
P00027=-52948,105572,55821,80,-58987,123448
//INST
///DATE 2010/06/07 13:23
///ATTR SC,RW
///GROUP1 RB1
NOP
*LABEL
DOUT OT#(1) OFF
DOUT OT#(2) OFF
DOUT OT#(9) OFF
DOUT OT#(8) OFF
WAIT IN#(1)=ON
MOVL P000 V=200.0
WAIT IN#(6)=ON
DOUT OT#(9) ON
MOVL P001 V=300.0
MOVL P002 V=200.0
WHILE IN#(1)=ON
        TIMER T=0.75
ENDWHILE
DOUT OT#(1) ON
TIMER T=0.50
MOVL P001 V=200.0
WAIT IN#(1)=OFF
MOVL P000 V=300.0
DOUT OT#(8) ON
WAIT IN#(3)=ON
DOUT OT#(9) OFF
DOUT OT#(8) OFF
MOVL P003 V=300.0
MOVL P004 V=200.0
TIMER T=0.50
DOUT OT#(1) OFF
TIMER T=1.00
MOVL P003 V=300.0
WAIT IN#(1)=ON
MOVL P000 V=300.0
DOUT OT#(9) ON
DOUT OT#(4) OFF
MOVL P023 V=200.0
MOVL P024 V=25.0
TIMER T=0.50
DOUT OT#(4) ON
TIMER T=0.50
MOVL P023 V=50.0
MOVL P000 V=200.0
MOVL P005 V=300.0
WHILE IN#(1)=ON
        DOUT OT#(1) OFF
        DOUT OT#(3) ON
        TIMER T=0.25
        MOVL P006 V=200.0
        TIMER T=0.25
        IFTHEN IN#(1)=OFF
                DOUT OT#(1) ON
                TIMER T=0.25
                DOUT OT#(3) OFF
                TIMER T=0.50
        ELSEIF IN#(1)=ON
                MOVL P005 V=150.0
                DOUT OT#(3) OFF
                TIMER T=0.50
        ENDIF
ENDWHILE
MOVL P005 V=200.0
WAIT IN#(1)=OFF
```

```
MOVL P000 V=300.0
DOUT OT#(8) ON
WAIT IN#(4)=ON
DOUT OT#(9) OFF
DOUT OT#(8) OFF
MOVL P007 V=300.0
TIMER T=0.10
MOVL P008 V=150.0
DOUT OT#(1) OFF
MOVL P020 V=50.0
MOVL P021 V=150.0
MOVL P000 V=100.0
MOVL P025 V=50.0
TIMER T=0.50
MOVL P026 V=25.0
TIMER T=0.50
MOVL P025 V=50.0
TIMER T=0.50
MOVL P000 V=100.0
DOUT OT#(9) ON
MOVJ P009 VJ=50.00
TIMER T=0.05
MOVL P010 V=300.0
WAIT IN#(1)=OFF
DOUT OT#(1) ON
TIMER T=0.20
MOVL P011 V=300.0
WAIT IN#(1)=OFF
MOVL P012 V=300.0
WAIT IN#(1)=OFF
MOVL P013 V=50.0
MOVL P014 V=250.0
TIMER T=0.75
MOVL P013 V=75.0
MOVL P000 V=300.0
DOUT OT#(8) ON
WAIT IN#(5)=ON
DOUT OT#(9) OFF
DOUT OT#(8) OFF
MOVL P015 V=300.0
WAIT IN#(1)=OFF
MOVL P016 V=50.0
WAIT IN#(2)=ON
DOUT OT#(2) ON
WAIT IN#(2)=OFF
DOUT OT#(2) OFF
WAIT IN#(2)=ON
WAIT IN#(1)=OFF
DOUT OT#(2) ON
WAIT IN#(2)=OFF
DOUT OT#(2) OFF
WAIT IN#(2)=ON
WAIT IN#(1)=OFF
MOVL P017 V=300.0
MOVL P018 V=300.0
MOVL P019 V=300.0
MOVL P022 V=250.0
DOUT OT#(1) OFF
TIMER T=0.50
MOVL P027 V=300.0
JUMP *LABEL
END
```

**G-Code**

**G Code sink2**

O4272
(K:\Common\ENGR 480\Common Flashlight Parts\G Code\sink2.ncl.1)
(04/27/10-11:42:26)
G56
N0010T5M06
S1800M03
G00X1.916Y.7388
G43Z.5H05
Z.05
G01Z-.06F8.
G02X1.9768Y.6777I-.0287J-.0892
G03X2.0232Y.6777I.0232J.0073
G02X2.084Y.7388I.0895J-.0281
G03X1.916Y.7388I-.084J.2612
G01Z-.12
G02X1.9768Y.6777I-.0287J-.0892
G03X2.0232Y.6777I.0232J.0073
G02X2.084Y.7388I.0895J-.0281
G03X1.916Y.7388I-.084J.2612
G01Z-.18
G02X1.9768Y.6777I-.0287J-.0892
G03X2.0232Y.6777I.0232J.0073
G02X2.084Y.7388I.0895J-.0281
G03X1.916Y.7388I-.084J.2612
G01Z-.24
G02X1.9768Y.6777I-.0287J-.0892
G03X2.0232Y.6777I.0232J.0073
G02X2.084Y.7388I.0895J-.0281
G03X1.916Y.7388I-.084J.2612
G01Z-.3
G02X1.9768Y.6777I-.0287J-.0892
G03X2.0232Y.6777I.0232J.0073
G02X2.084Y.7388I.0895J-.0281
G03X1.916Y.7388I-.084J.2612
G01Z-.36
G02X1.9768Y.6777I-.0287J-.0892
G03X2.0232Y.6777I.0232J.0073
G02X2.084Y.7388I.0895J-.0281
G03X1.916Y.7388I-.084J.2612
G01Z-.42
G02X1.9768Y.6777I-.0287J-.0892
G03X2.0232Y.6777I.0232J.0073
G02X2.084Y.7388I.0895J-.0281
G03X1.916Y.7388I-.084J.2612
G01Z-.435
G02X1.9768Y.6777I-.0287J-.0892
G03X2.0232Y.6777I.0232J.0073
G02X2.084Y.7388I.0895J-.0281
G03X1.916Y.7388I-.084J.2612
G01Z.5
N0020T6M06
S1800M03
G00X1.9721Y.6369
G43Z.5H06
Z-.3231
G01Z-.4331F10.
X2.0279
G03X2.053Y.6683I-.0279J.0481
G02X2.0713Y.6964I.0597J-.0187
G01X1.9287
G03X1.9065Y.709I-.0414J-.0468
G02X1.8162Y.7558I.0935J.291
G01X2.1838
G03X2.2435Y.8153I-.1838J.2442
G01X1.7565
G02X1.7212Y.8748I.2435J.1847
G01X2.2788
G03X2.2984Y.9342I-.2788J.1252
G01X1.7016
G02X1.6945Y.9937I.2984J.0658
G01X2.3055
G03X2.301Y1.0531I-.3055J.0063
G01X1.699
G02X1.7159Y1.1126I.301J-.0531
G01X2.2841
G03X2.2526Y1.172I-.2841J-.1126
G01X1.7474
G02X1.8005Y1.2315I.2526J-.172
G01X2.1995
G03X2.0935Y1.291I-.1995J-.2315
G01X1.9065
G03X1.9065Y.709I.0935J-.291
G02X1.947Y.6683I-.0192J-.0594
G03X2.053Y.6683I.053J.0167
G02X2.0935Y.7091I.0597J-.0187
G03X1.9201Y1.295I-.0935J.2909
G01X1.9065Y1.291
X2.2435Y.8153
Z-.435
X2.1347
G03X2.1557Y.8299I-.0245J.0575
G01X2.1667Y.8461
X2.1722Y.8656
X2.1727Y.8728
Y.8748
X2.2788
G03X2.2984Y.9342I-.2788J.1252
G01X2.1727
Y.9937
X2.3055
G03X2.301Y1.0531I-.3055J.0063
G01X2.1727
Y1.1126

X2.2841
G03X2.2526Y1.172I-.2841J-.1126
G01X2.1536
X2.137Y1.1836
X2.1189Y1.1888
X1.9065Y1.291
X2.0935
G02X2.1995Y1.2315I-.0935J-.291
G01X1.8005
G03X1.7474Y1.172I.1995J-.2315
G01X1.8463
X1.7474
G03X1.7159Y1.1126I.2526J-.172
G01X1.8273
Y1.0531
X1.699
G03X1.6945Y.9937I.301J-.0531
G01X1.8273
Y.9342
X1.7016
G03X1.7212Y.8748I.2984J.0658
G01X1.8273
Y.8728
X1.8283Y.8622
X1.8286Y.8606
G03X1.8464Y.828I.0534J.008
G01X1.863Y.8164
X1.8667Y.8153
X1.7565
G03X1.8162Y.7558I.2435J.1847
G01X2.1838
X1.8162
G03X1.9065Y.7091I.1838J.2442
G01X1.9137Y.7062
X1.9278Y.6964
X2.0711
X2.0678Y.6929
X2.056Y.6759
X2.053Y.6683
G02X2.0279Y.6369I-.053J.0167
G01X1.9721
X2.0309Y.8103
X2.1102
X2.1209Y.8114
X2.1218
G03X2.1557Y.8299I-.0116J.0614
G01X2.1667Y.8461
X2.1722Y.8656
X2.1727Y.8728
Y1.1272
X2.1717Y1.1378
X2.1714Y1.1394
G03X2.1536Y1.172I-.0534J-.008
G02X2.1714Y1.1394I-.0356J-.0406
G01X2.1716Y1.1388
X2.1717Y1.1378
X2.1727Y1.1272
Y.8728
X2.1722Y.8656
X2.1667Y.8461
X2.1557Y.8299
G02X2.1218Y.8114I-.0455J.0429
G01X2.1209
X2.1102Y.8103
X1.8898
X1.8825Y.8109
X1.863Y.8164
X1.8464Y.828
G02X1.8286Y.8606I.0356J.0406
G01X1.8284Y.8612
X1.8283Y.8622
X1.8273Y.8728
Y1.1272
X1.8278Y1.1344
X1.8333Y1.1539
X1.8443Y1.1701
G02X1.8782Y1.1886I.0455J-.0429
G01X1.8791
X1.8898Y1.1897
X2.1102
X2.1175Y1.1891
X2.137Y1.1836
X2.1536Y1.172
Z.5
G00X2.0678Y.6929
Z-.3831
G01Z-.435
G02X2.0935Y.7091I.0398J-.0349
G03X1.9065Y.7091I-.0935J.2909
G01X1.9137Y.7062
X1.9307Y.6944
G02X1.947Y.6683I-.0349J-.0399
G03X2.053Y.6683I.053J.0167
G01X2.056Y.6759
X2.0678Y.6929
Z.5
G00X1.9818Y.685
Z-.385
G01Z-.475F8.
G03X1.9818Y.685I.0182J0.
G01Z.5
M30

**G-Code Flashlight Head**

```
%
O1;  (FLASHLIGHT HEAD)
;   (STOCK: ALUM 1.5" x 35 + 10 mm)
;   (Alum cutting speed: 75 m/min rough, 185 m/min
finish)
;
;   (Variables)
#500=38.1       (STOCK DIAMETER)
#501=34.24      (STOCK LENGTH)
#502=75.0       (ROUGH SURFACE M/MIN)
#503=0.2        (ROUGHING FEED: MM/REV)
#504=185.0          (FINISH SURFACE M/MIN)
#505=0.05           (FINISH FEED MM/REV)
;
;(FACING PROCEDURE)
N1
G54                 (WORK OFFSET)
G21                 (CHOOSE METRIC SYSTEM)
G28   U0   W0           (GO HOME)
G50   S2000             (SET MAX SPINDLE SPEED)
G00   T1010             (SELECT CUT-OFF TOOL)
G96   S#502             (SET CONSTANT SURFACE
SPEED)
G99                 (FEED PER REV)
M03                 (SPINDLE ON)
G00   X[#500+1.0] Z#501
M08
G01   X-1.0   F#503
G01   Z[#501+1.0]   F1.0
M09
M05
G28   U0   W0
M01
;
; (ROUGH PASS - ROUGH USING 2.0 MM DOC/PASS)
;
N2
G28 U0 W0                   (GO HOME FOR TOOL
CHANGE)
G50 S2000                   (SET MAX SPINDLE SPEED)
G96 S#502                   (SET SURFACE SPEED)
G99
G00 T0101                           (CHANGE TO
ROUGHING TOOL)
G00 X[#500+1.0] Z[#501+1.0]    (GO TO INITIAL
POINT FOR ROUGHING)
M03                         (START SPINDLE)
M08
N020 G71 U2.0 R1.0                  (ROUGHING
CYCLE CODE)
N021 G71 P022 Q028 U1.0 W0.5 F#503
N022 G01 X30.032 Z[#501+1.0]    (INITIAL
ROUGHING POINT)
N023 G01 X30.032 Z25.74
N024 G01 X33.032 Z25.74
N025 G01 X33.032 Z17.74
N026 G01 X35.032 Z17.74
N027 G01 X35.032 Z-3.05
N028 G01 X[#500+1.0] Z-3.05
M09
M05
G01 X[#500+1.0]
G28 U0 W0                   (GO HOME FOR TOOL
CHANGE)
M01                                 (OPTIONAL STOP)
G00 T0202                   (FINISHING TOOL)
G50 S2000                   (SET MAX SPINDLE SPEED)
G96 S#504                   (SET SURFACE SPEED)
G99
G00 X[#500+1.0] Z[#501+1.0]    (RETURN TO PART)
M03                                 (SPINDLE ON
CCW)
M08                                 (COOLANT ON)
N028 G70 P022 Q028 F0.05                (FINISHING
PASS)
G01 X[#500+1.0]             (MOVE TOOL AWAY FROM
WORK)
M09                                 (COOLANT OFF)
M05                                 (STOP SPINDLE)
G28 U0 W0                           (GO HOME)
M01                                 (OPTIONAL STOP)
;
; (THREADING)
N3
G28 U0 W0
G00 T0303      (THREADING TOOL)
G50 S2000      (SET MAX SPINDLE SPEED)
G96 S#502      (SET SURFACE SPEED)
G99
G00 X30.032 Z36.0
M03             (SPINDLE ON FORWARD)
M08             (COOLANT ON)
G76 P160060
G76 X28.3 Z25.24 P866 Q100 F1.0
M09             (COOLANT OFF)
M05             (SPINDLE OFF)
G28 U0 W0       (HOME)
M01             (OPTIONAL STOP)
;
; (CENTER DRILL PILOT HOLE)
N4
G28 U0 W0
G00 T0505                           (CENTER DRILL,
TOOL 5)
```

```
G97 S1000                    (SET SPINDLE SPEED)
G99
G00 X0.0 Z[#501+2.0]                (SAFE POINT)
M03                                 (SPINDLE ON
CCW)
M08                                 (COOLANT ON)
G01 X0.0 Z[#501-4.0] F#503
G01 X0.0 Z[#501+2.0] F2.0(SAFE POINT)
M09                                 (COOLANT OFF)
M05                                 (SPINDLE OFF)
G28 U0 W0
M01
;
; (PECK DRILLING WITH 1/2" DRILL)
N5
G28 U0 W0         (HOME)
G00 T1212         (TOOL CHANGE TO 1/2" DRILL)
G97 S1200      (SET SPINDLE SPEED)
G99
G00 X0.0
G00 Z36.0         (SAFE POINT)
M03               (SPINDLE ON CCW)
M08               (COOLANT ON)
G01 Z30.0 F#503  (CUTTING)
G01 Z36.0 F1.0
G01 Z25.0 F#503  (CUTTING)
G01 Z36.0 F1.0
G01 Z20.0 F#503  (CUTTING)
G01 Z36.0 F1.0
G01 Z15.0 F#503  (CUTTING)
G01 Z36.0 F1.0
G01 Z10.0 F#503  (CUTTING)
G01 Z36.0 F1.0
G01 Z5.0 F#503    (CUTTING)
G01 Z36.0 F1.0
G01 Z0.0 F#503    (CUTTING)
G01 Z36.0 F1.0
G01 Z-1.0 F#503  (CUTTING)
G01 Z40.0 F1.0    (SAFE POINT)
M09               (COOLANT OFF)
M05               (SPINDLE OFF)
G28 U0 W0         (HOME)
M01               (OPTIONAL STOP)
;
; (PECK BORING WITH 3/4" END MILL)
N6
G28 U0 W0         (HOME)
G00 T0707         (TOOL CHANGE TO END MILL)
G97 S1000      (SET SPINDLE SPEED)
G99
G00 Z36.0
G00 X18.7         (SAFE POINT)
M03               (SPINDLE ON CCW)
M08               (COOLANT ON)
G01 Z30.0 F#503  (CUTTING)
G01 Z36.0 F1.0
G01 Z25.0 F#503  (CUTTING)
G01 Z36.0 F1.0
G01 Z20.0 F#503  (CUTTING)
G01 Z36.0 F1.0
G01 Z15.0 F#503  (CUTTING)
G01 Z36.0 F1.0
G01 Z10.0 F#503  (CUTTING)
G01 Z36.0 F1.0
G01 Z5.0 F#503    (CUTTING)
G01 Z36.0 F1.0
G01 Z1.5 F#503    (CUTTING)
G04 F0.5(DWELL)
G01 Z40.0 F1.0    (SAFE POINT)
M09               (COOLANT OFF)
M05               (SPINDLE OFF)
G28 U0 W0         (HOME)
M01               (OPTIONAL STOP)
;
; (ROUGHING CYCLE WITH 3/4" END MILL)
N7
G28 U0 W0         (HOME)
G00 T0707         (TOOL CHANGE TO END MILL)
G96 S#502      (SET SURFACE SPEED)
G50 S2000      (SET MAX SPINDLE SPEED)
G99
G00 X18.7 Z36.0  (SAFE POINT)
M03               (SPINDLE ON CCW)
M08               (COOLANT ON)
G71 U1.0 R0.5
G71 P40 Q50 U-0.6 W0.3 F#503
N40 G01 X26.4 Z34.24
   G01 X25.4 Z33.74
   G01 X25.4 Z4.915
   G01 X21.05 Z3.24
N50 G01 X21.05 Z1.0
G01 X18.7 Z36.0  (SAFE POINT)
M09               (COOLANT OFF)
M05               (SPINDLE OFF)
G28 U0 W0         (HOME)
M01               (OPTIONAL STOP)
; (MANUAL CHIP CLEARING)
;
; (14.5MM BORING BAR ROUGHING CYCLE)
N8
G28 U0 W0                   (HOME)
```

```
G00 T0909                    (TOOL CHANGE TO
BORING BAR)
G50 S2000          (SET MAX SPINDLE SPEED)
G96 S#502          (SET SURFACE SPEED)
G99
G00 X14.8 Z36.0              (SAFE POINT)
M03                          (SPINDLE ON CCW)
M08                          (COOLANT ON)
G01 Z-1.5 F#503              (CUTTING)
G01 X14.7 Z1.6 F1.0
G01 X15.2
G01 Z-1.5 F#503              (CUTTING)
G01 X14.8 Z1.6 F1.0
G01 X15.9
G01 Z-1.5 F#503   (CUTTING)
G00 X15.0 Z36.0 F1.0         (SAFE POINT)
M09                          (COOLANT OFF)
M05                          (SPINDLE OFF)
G28 U0 W0                    (HOME)
M01                          (OPTIONAL STOP)
; (MANUAL CHIP CLEARING IF NECESSARY)
;
; (BORING BAR FINISHING CYCLE)
N9
G28 U0 W0          (HOME)
G50 S2000
G96 S#504
G99
G00 X16.0 Z36.0   (SAFE POINT)
M03               (SPINDLE ON CCW)
M08               (COOLANT ON)
G70 P60 Q70 F#505
N60 G01 X26.4 Z34.24
   G01 X25.4 Z33.74
   G01 X25.4 Z4.915
   G01 X21.05 Z3.24
   G01 X21.05 Z1.0
   G01 X16.7 Z1.0
N70 G01 X16.7 Z-1.5
G01 X16.0 Z36.0   (SAFE POINT)
M09               (COOLANT OFF)
M05               (SPINDLE OFF)
G28 U0 W0         (HOME)
M01               (OPTIONAL STOP)
;
; (END AND NOSE CHAMFER)
N10
G28 U0 W0    (GO HOME FOR TOOL CHANGE)
G50 S2000
G96 S#502
G99
G00 T0202
M03
G00 X[#500+1.0] Z[#501-1.0]
M08
G01 X30.032 Z[#501-1.0]F#503
G01 X29.032 Z#501
G01 X[#500+1.0]
G00 X[#500+1.0] Z13.0
G71 U1.0 R0.5
G71 P030 Q033 U1.0 W0.5 F#503
N030 G01 X37.032 Z7.0
N031 G01 X21.032 Z-1.0
N032 G01 X21.032 Z-3.5
N033 G01 X[#500+1.0] Z-3.5
G70 P030 Q033 F0.05 S#504
M09
M05
G28 U0 W0
M01
;
;(CUTOFF)
N11
G28 U0 W0
G00 T1010
G50 S2000       (SET MAX SPINDLE SPEED)
G96 S#504       (SET SURFACE SPEED)
G99
G00 X[#500+1.0] Z-3.0
M03
M08
G01 X-.5 Z-3.0 F#505
G01 X[#500+1.0] F#505
M09
M05
G28 U0 W0
M30
```

**G-Code  Magnet Ring**

```
%
O0510
; (FLASHLIGHT MAGNET RING)
; (ERIK BIESENTHAL)
; (1.5" x 14MM + 10MM)
; (ALUM CUTTING SPEED: 75M/MIN ROUGH)
;
; (VARIABLES)
#500=38.1                (STOCK DIAMETER)
#501=13.25               (STOCK LENGTH)
#502=75.0                (SURFACE M/MIN)
#503=0.4                 (ROUGHING FEED:
MM/REV)
#504=0.4                 (NOSE RADIUS VALUE -
mm)
;
N1
G54                      (WORK OFFSET)
G21                      (METRIC)
G28 U0 W0                (GO HOME)
;
; (FACING WITH PARTING TOOL AND SPEED
LIMITING)
;
G00 T1010                (CUTOFF TOOL)
G50 S1000                (CLAMP SPEED AT
1000RPM)
G96 S#502                (CONST SURFACE SPEED)
G99                      (FEED PER REV)
M03                      (SPINDLE ON, NORMAL
DIR)
G00 Z#501                (INITIAL Z POSITION)
G00 X[#500+1]            (INITIAL X POSITION)
M08                      (COOLANT ON)
G01 X-0.01 F#503(FACE FROM OUTSIDE DOWN TO -
0.01)
G01 Z[#501+1.0] F1.0     (MOVE OFF FROM FACE)
M09                      (TURN OFF COOLANT)
M05                      (TURN OFF SPINDLE)
G28 U0 W0                (GO HOME)
M01                      (OPTIONAL STOP)
;
; (CONTOURING - O.D. PROFILING)
;
N2
G00 T0202                (FINISHING TOOL FOR OD
PROFILE)
G50 S2000                (CLAMP SPEED AT
2000RPM)
G96 S#502                (CONST SURFACE SPEED)
G99                      (FEED PER REV)
G00 X#500 Z13.02         (INITIAL POINT FOR
PROFILING PASS)
M03                      (SPINDLE ON)
M08                      (COOLANT ON)
G71 U1.0 R1.5            (ROUGHING CYCLE)
G71 P21 Q22 U0.5 W0.0 F#503
N21     G42 X33.1  Z15.77 D#504
        G01 X36.4  Z11.25 D#504
        G01 X36.4  Z2.0   D#504
        G01 X34.94 Z0.0   D#504
        G01 X34.94 Z-3.0  D#504
N22     G01 X#500  Z-3.0  D#504
G00 X#500 Z#501          (SP)
G70 P21 Q22 F0.1         (FINISHING CYCLE)
G40 G00 X#500 Z#501      (SP - NOSE RADIUS
OFFSET CANCEL)
M09                      (COOLANT OFF)
M05                      (SPINDLE STOP)
G28 U0 W0                (RETURN HOME)
M01                      (OPTIONAL STOP
;
; (CENTER DRILLING)
;
N3
G00 T0505                (CENTER DRILLING TOOL)
G97 S1500                (DRILL AT 1400RPM)
G99                      (FEED PER REV)
G00 X0.0 Z[#501+1.0]     (START POINT)
M03                      (SPINDLE ON)
M08                      (COOLANT ON)
G01 Z[#501-3.0]   F0.1   (FEED DRILL)
G01 Z[#501+1.0]  F1.0    (RETRACT DRILL)
M09                      (COOLANT OFF)
M05                      (SPINDLE STOP)
G28 U0 W0                (RETURN HOME)
M01                      (OPTIONAL STOP)
;
; (DRILLING - 19/32" DRILL)
;
N4
G00 T1212                (19/32" DRILL)
G97 S1000                (DRILL AT 1000RPM)
G99                      (FEED PER REV)
G00 X0.0 Z[#501+1.0]     (DRILL START POINT)
M03                      (SPINDLE ON)
M08                      (COOLANT ON)
G01 Z8.0 F0.1            (DRILL FEED)
G01 Z[#501+1.0] F1.0     (DRILL RETRACT)
G01 Z3.0 F0.1            (DRILL FEED)
G01 Z[#501+3.0] F1.0     (DRILL RETRACT)
G01 Z-1.5 F0.1           (DRILL FEED)
G01 Z[#501+3.0] F1.0     (DRILL RETRACT)
M09                      (COOLANT OFF)
```

```
M05                     (SPINDLE STOP)
G28 U0 W0               (RETURN HOME)
M01                     (OPTIONAL STOP)
;
;(BORING WITH END MILL - ROUGHING)
;
N5
G00 T0707               (18.0MM OD END MILL)
G50 S1000               (CLAMP SPEED AT
1000RPM)
G96 S#502               (CONST SURFACE SPEED)
G99                     (FEED PER REV)
G00 X19.0 Z[#501+1.0]   (BORING START POINT)
M03                     (COOLANT ON)
M08                     (SPINDLE ON)
G01 Z8.0 F0.1           (FIRST PASS)
G01 Z[#501+0.5] F1.0
G01 Z3.0 F0.1
G01 Z[#501+3.0] F1.0
G01 Z-1.5 F0.1
G01 Z[#501+0.5] F1.0
G00 X22.0               (SECOND PASS)
G01 Z8.0 F0.1
G01 Z[#501+0.5] F1.0
G01 Z3.0 F0.1
G01 Z[#501+3.0] F1.0
G01 Z-1.5 F0.1
G01 Z[#501+0.5] F1.0
G00 X25.0               (THIRD PASS)
G01 Z8.0 F0.1
G01 Z[#501+0.5] F1.0
G01 Z3.0 F0.1
G01 Z[#501+3.0] F1.0
G01 Z-1.5 F0.1
G01 Z[#501+0.5] F1.0
G00 X28.0               (FOURTH PASS)
G01 Z8.0 F0.1
G01 Z[#501+0.5] F1.0
G01 Z3.0 F0.1
G01 Z[#501+3.0] F1.0
G01 Z-1.5 F0.1
G01 Z[#501+0.5] F1.0
G00 X31.0               (FIFTH PASS)
G01 Z8.0 F0.1
G01 Z[#501+0.5] F1.0
G01 Z3.0 F0.1
G01 Z[#501+3.0] F1.0
G01 Z-1.5 F0.1
G01 Z[#501+1.0] F1.0
M09                     (COOLANT OFF)
M05                     (SPINDLE OFF)
G28 U0 W0               (RETURN HOME)
M01                     (OP STOP)
;
;(BORING WITH BORING BAR - ROUGHING AND
FINISHING)
;
N6
G00 T0909               (14.4MM MIN DIAM
BORING BAR)
G50 S1200               (CLAMP SPEED AT
1200RPM)
G96 S#502               (CSS)
G99                     (FEED PER REV)
G00 X32.0 Z[#501+1.0]   (BORING START POINT)
M03
M08
G01 Z-1.5 F0.1          (PASS 1- FEED Z)
G01 X30.5 F0.5          (RETRACT X)
G00 Z[#501+0.5]         (RETRACT Z)
G00 X33.1               (POSITION X FOR PASS 2)
G01 Z-1.5 F0.1          (PASS 2 - FEED Z)
G01 X31.0 F0.5          (RETRACT X)
G00 Z[#501+1.0]         (RETRACT Z)
M09                     (COOLANT OFF)
M05                     (SPINDLE STOP)
G28 U0 W0               (RETURN HOME)
M01                     (OP STOP)
;
;(CUTTING THE MAGNET GROOVE)
;
N7
G00 T0808               (ID THREADING TOOL)
G50 S1200               (CLAMP SPEED AT
1200RPM)
G96 S#502               (CSS)
G99                     (FEED PER REV)
G00 X33.0 Z[#501+0.5]   (SP)
M03                     (SPINDLE ON)
M08                     (COOLANT ON)
G01 Z5.75 F1.0          (POSITION IN Z)
G01 X34.0 F0.3          (FEED X)
G01 Z0.75 F0.1          (FEED Z)
G01 X33.0 F0.5          (RETRACT X)
G01 Z5.75 F0.5          (RETRACT Z)
G01 X35.0 F0.3          (FEED X)
G01 Z0.75 F0.1          (FEED Z)
G01 X33.0 F0.5          (RETRACT X)
G01 Z[#501+1.0] F1.0    (RETRACT Z)
M09                     (COOLANT OFF)
M05                     (SPINDLE STOP)
G28 U0 W0               (RETURN HOME)
```

```
M01                     (OP STOP)
;
; (PARTING)
;
N8
G00 T1010               (PARTING TOOL)
G97 S1000               (SPINDLE SPEED OF
1000RPM)
G00 X#500 Z-3.0         (CUTOFF BLADE IS 3.0MM
WIDE)
M03                     (SPINDLE ON)
M08                     (COOLANT ON)
G01 X-0.1 F0.05         (CUTOFF)
G00 Z#501               (RETRACT OFF OF FACE)
M09                     (COOLANT OFF)
M05                     (SPINDLE STOP)
G28 U0 W0               (RETURN HOME)
M30                     (IT IS FINISHED!!!!!)
%
```

**G-Code  Flashlight Body**

```
%
O2 (FLASHLIGHT BODY )
; (FLASHLIGHT BODY 2010-5-31)
; (STOCK: ALUM 1.5" X 88MM + 10MM)
; (ALUM CUTTING SPEED: 75M/MIN ROUGH,
185M/MIN FINISH)
;
; (VARIABLES)
#500=38.1    (STOCK DIAMETER)
#501=88.0    (STOCK LENGTH)
#502=75.0    (SURFACE M/MIN)
#503=0.4     (ROUGHING FEED: MM/REV)
#504=0.1     (FINISH FEED: MM/REV)
#505=18.13   (DIAMETER OF END MILL FOR BORING)
#506=35.0   (MAX OD OF FINISHED PART)

;
; (FACING CUTOFF)
;
N1 (FACING CUTOFF)
G54              (WORK OFFSET)
G21              (METRIC)
;
G28 U0 W0          (GO HOME)
G50 S1000          (MAX SPINDLE SPEED)
G00 T1010          (CUTOFF TOOL)
G50 S1000          (CLAMP SPEED AT 1000RPM)
G96 S#502          (CONST SURF SPEED)
G99              (FEED PER REV)
M03               (SPINDLE ON, NORMAL DIR)
G00 X[#500+1.0]  Z#501      (INITIAL POSITION)
M08                (TURN ON COOLANT)
G01 X-0.4 F#503          (FACE FROM OUTSIDE
DOWN TO -0.4)
M09                (TURN OFF COOLANT)
G00 X[#500+2.0]          (RETRACT)
M05                (TURN OFF SPINDLE)
G28 U0 W0     (RETURN TO HOME)
M01          (OPTIONAL STOP)
;
; (CENTER DRILLING)
;
N2             (CENTER DRILL)
G00 T0505        (CENTER DRILL, TOOL 5)
G97 S1000        (1000RPM)
G99
M03      (SPINDLE ON)
G00 X0 Z[#501 + 2.0]
M08      (COOLANT ON)
G01 X0 Z[#501 - 2.0] F0.5
G01 X0 Z[#501 + 2.0] F2.0
M09
M05
G28 U0 W0
M01
;
(DRILLING OPPERATION)
N3             (DRILLING)
G00 T1212        (0.5IN DRILL, TOOL 12)
G97 S1000        (1000RPM)
G99
M03      (SPINDLE ON)
G00 X0.0 Z[#501 + 2.0]
M08      (COOLANT ON)
G01 X0.0 Z[#501-5.0] F0.5
G01 X0.0 Z[#501 + 2.0] F2.0
G01 X0.0 Z[#501-10.0] F0.5
G01 X0.0 Z[#501 + 2.0] F2.0
G01 X0.0 Z[#501-15.0] F0.5
G01 X0.0 Z[#501 + 2.0] F2.0
G01 X0.0 Z[#501-20.0] F0.5
G01 X0.0 Z[#501 + 2.0] F2.0
G01 X0.0 Z[#501-25.0] F0.5
G01 X0.0 Z[#501 + 2.0] F2.0
G01 X0.0 Z[#501-30.0] F0.5
G01 X0.0 Z[#501 + 2.0] F2.0
G01 X0.0 Z[#501-35.0] F0.5
G01 X0.0 Z[#501 + 2.0] F2.0
G01 X0.0 Z[#501-40.0] F0.5
G01 X0.0 Z[#501 + 2.0] F2.0
G01 X0.0 Z[#501-45.0] F0.5
G01 X0.0 Z[#501 + 2.0] F2.0
G01 X0.0 Z[#501-50.0] F0.5
G01 X0.0 Z[#501 + 2.0] F2.0
G01 X0.0 Z[#501-55.0] F0.5
G01 X0.0 Z[#501 + 2.0] F2.0
G01 X0.0 Z[#501-60.0] F0.5
G01 X0.0 Z[#501 + 2.0] F2.0
G01 X0.0 Z[#501-65.0] F0.5
G01 X0.0 Z[#501 + 2.0] F2.0
G01 X0.0 Z[#501-70.0] F0.5
G01 X0.0 Z[#501 + 2.0] F2.0
G01 X0.0 Z[#501-73.0] F0.5
G01 X0.0 Z[#501 + 2.0] F2.0
M09    (TURN COOLANT OFF)
M05    (TURN SPINDLE OFF)
G28 U0 W0       (GO HOME)
M01          (OPTIONAL STOP)
;
N4
;(BORING WITH END MILL)
G00 T0707   (TOOL CHANGE END MILL TOOL 7)
G97 S800        (800RPM)
G99
M03       (SPINDLE ON)
```

```
G00 X#505 Z[#501+2.0]
M08        (COOLANT ON)
(BORING PASS 1)
G01 X#505 Z[#501-5.0] F0.5   (THIS MAKES INNER
DIAMETER 18.13)
G01 Z[#501+2.0] F2.0
G01 Z[#501-10.0] F0.5
G01 Z[#501+2.0] F2.0
G01 Z[#501-15.0] F0.5
G01 Z[#501+2.0] F2.0
G01 Z[#501-20.0] F0.5
G01 Z[#501+2.0] F2.0
G01 Z[#501-25.0] F0.5
G01 Z[#501+2.0] F2.0
G01 Z[#501-30.0] F0.5
G01 Z[#501+2.0] F2.0
G01 Z[#501-35.0] F0.5
G01 Z[#501+2.0] F2.0
G01 Z[#501-40.0] F0.5
G01 Z[#501+2.0] F2.0
G01 Z[#501-45.0] F0.5
G01 Z[#501+2.0] F2.0
G01 Z[#501-50.0] F0.5
G01 Z[#501+2.0] F2.0
G01 Z[#501-55.0] F0.5
G01 Z[#501+2.0] F2.0
G01 Z[#501-60.0] F0.5
G01 Z[#501+2.0] F2.0
G01 Z[#501-65.0] F0.5
G01 Z[#501+2.0] F2.0
G01 Z[#501-70.0] F0.5
G01 Z[#501+2.0] F2.0
G01 Z[#501-73.0] F0.5
G01 Z[#501+2.0] F2.0
(BORING PASS #2)
G01 X[#505+0.8] Z[#501+2.0] F2.0     (THIS MAKES
INNER DIAMETER 18.13+0.8 = 18.93)
G01 Z[#501-10.0] F0.5
G01 Z[#501+2.0] F2.0
G01 Z[#501-15.0] F0.5
G01 Z[#501+2.0] F2.0
G01 Z[#501-20.0] F0.5
G01 Z[#501+2.0] F2.0
G01 Z[#501-25.0] F0.5
G01 Z[#501+2.0] F2.0
G01 Z[#501-30.0] F0.5
G01 Z[#501+2.0] F2.0
G01 Z[#501-35.0] F0.5
G01 Z[#501+2.0] F2.0
G01 Z[#501-40.0] F0.5
G01 Z[#501+2.0] F2.0
G01 Z[#501-45.0] F0.5
G01 Z[#501+2.0] F2.0
G01 Z[#501-50.0] F0.5
G01 Z[#501+2.0] F2.0
G01 Z[#501-55.0] F0.5
G01 Z[#501+2.0] F2.0
G01 Z[#501-60.0] F0.5
G01 Z[#501+2.0] F2.0
G01 Z[#501-65.0] F0.5
G01 Z[#501+2.0] F2.0
G01 Z[#501-70.0] F0.5
G01 Z[#501+2.0] F2.0
G01 Z[#501-73.0] F0.5
G01 Z[#501+2.0] F2.0
;
;(BORING PASS 3 - THREADED SECTION)
;
G01 X28.0 F0.5
G01 Z#501 F0.5
G01 Z77.2 F0.5
G01 X18.5 Z73.0 F0.5
G01 Z[#501+5.0] F2.0
;
M09    (TURN COOLANT OFF)
M05    (TURN SPINDLE OFF)
G28 U0 W0       (GO HOME)
M01            (OPTIONAL STOP)
;
;(BORING WITH BORING BAR)
;
N5
G28 U0 W0       (GOING HOME - JUST TO MAKE
SURE)
G00 T0909       (TOOL CHANGE - BORING BAR TOOL
9)
G97 S1000       (1000RPM)
G99
M03        (SPINDLE ON)
G00 X31.5 Z[#501+5.0]
M08        (COOLANT ON)
G01 Z#501 F0.1
G01 X30.5 Z87.5 F0.1 (CHAMFER)
G01 Z86.0 F0.1
G01 X28.4 F0.1
G01 Z77.0 F0.1
G01 X19.05 Z72.33 F0.1
G01 Z15.0 F0.1
G01 X15.0 Z13.0 F0.1
G01 Z[#501+5.0] F2.0   (RETRACT AWAY FROM PART)
M09       (COOLANT OFF)
M05       (SPINDLE STOP)
```

```
G28 U0 W0       (GO HOME)
M01       (OPTIONAL STOP)
;
; (ID THREADING)
;
N6
G28 U0 W0
G00 T0808                   (THREADING TOOL)
G97 S1000
G00 X28.4 Z[#501+2.0]
M03                         (SPINDLE ON FORWARD)
M08                         (COOLANT ON)
G76 P160060
G76 X30.132 Z77.0 P866 Q100 F1.0
G01 X25.0 F2.0        (RETRACT X)
G01 Z[#501+5.0]
M09                         (COOLANT OFF)
M05                         (SPINDLE OFF)
G28 U0 W0                   (HOME)
M01                         (OPTIONAL STOP)

;
; (OD ROUGH TURNING)
;
N7
G28 U0 W0       (GOING HOME - JUST TO MAKE
SURE)
G00 T0101        (55DEG DIAMOND TOOL, TOOL 1)
G50 S2000        (CLAMP SPEED AT 2000)
G96 S#502        (CONST SURF SPEED)
G99             (FEED PER REV)
M03             (SPINDLE ON)
M08             (COOLANT ON)
G00 X[#500-2.9] Z[#501+2.0]    (GETS CLOSE)
G01 Z-0.3 F0.4      (MAKES DIAMETER = 38.1 - 2.9 =
35.2)
M09       (COOLANT OFF)
G01 X#500 F2.0          (RETRACTS FROM SURFACE)
G01 Z[#501+5.0] F2.0      (RETRACTS TO Z START)
M05       (SPINDLE STOP)
G28 U0 W0  (GO HOME)
M01       (OPTIONAL STOP)
;
; (CUTTING GROOVES WITH PARTING TOOL)
;
N8
#514=32.1       (MINOR DIAMETER OF GROOVES)
G28 U0 W0       (GOING HOME - JUST TO MAKE
SURE)
G00 T1010          (CUTOFF TOOL)
G50 S1000          (CLAMP SPEED AT 1000RPM)
G96 S#502          (CONST SURF SPEED)
G99               (FEED PER REV)
M03               (SPINDLE ON, NORMAL DIR)
#507=66.0          (STARTING POINT OF FIRST
GROOVE)
G00 Z[#507+1.5]      (GETS CLOSE IN Z)
G00 X#500          (GETS CLOSE IN X)
M08               (COOLANT ON)
G01 X#514 F#504
G01 X#500 F2.0
G01 Z[#507+6.5-3.0] F2.0
G01 X#514 F#504
G01 X#500 F2.0
M09               (COOLANT OFF)
#507=52.5          (START POINT OF SECOND
GROOVE)
G00 Z[#507+1.5]      (GETS CLOSE IN Z)
G00 X#500          (GETS CLOSE IN X)
M08               (COOLANT ON)
G01 X#514 F#504
G01 X#500 F2.0
G01 Z[#507+6.5-3.0] F2.0
G01 X#514 F#504
G01 X#500 F2.0
M09               (COOLANT OFF)
#507=39.0          (START POINT OF THIRD GROOVE)
G00 Z[#507+1.5]      (GETS CLOSE IN Z)
G00 X#500          (GETS CLOSE IN X)
M08               (COOLANT ON)
G01 X#514 F#504
G01 X#500 F2.0
G01 Z[#507+6.5-3.0] F2.0
G01 X#514 F#504
G01 X#500 F2.0
M09               (COOLANT OFF)
#507=25.5          (START POINT OF FOURTH
GROOVE)
G00 Z[#507+1.5]      (GETS CLOSE IN Z)
G00 X#500          (GETS CLOSE IN X)
M08               (COOLANT ON)
G01 X#514 F#504
G01 X#500 F2.0
G01 Z[#507+6.5-3.0] F2.0
G01 X#514 F#504
G01 X#500 F2.0
M09               (COOLANT OFF)
#507=12.0          (START POINT OF FIFTH GROOVE)
G00 Z[#507+1.5]      (GETS CLOSE IN Z)
G00 X#500          (GETS CLOSE IN X)
M08               (COOLANT ON)
G01 X#514 F#504
```

```
G01 X#500 F2.0
G01 Z[#507+6.5-3.0] F2.0
G01 X#514 F#504
G01 X[#500+5.0] F2.0
M09              (COOLANT OFF)
G00 Z-3.3
M08              (COOLANT ON)
G01 X26.0 F0.1       (PARTIAL CUTOFF FOR CHAMFER)
G01 X#500 F2.0       (RETRACT X)
G01 X35.0 Z-1.5 F0.5
G01 X31.5 Z-3.1 F0.1
G01 X[#500+5.0]      (RETRACT X)
M09              (COOLANT OFF)
M05              (SPINDLE OFF)
G00 Z[#501+5.0]      (RETRACT Z)
G28 U0 W0       (GO HOME)
M01           (OPTIONAL STOP)
;
; (OD FINISHING PASS)
;
N9
G28 U0 W0        (GOING HOME - JUST TO MAKE
SURE)
G00 T0202        (FINISHING TOOL)
G50 S2000        (CLAMP SPEED AT 2000)
G96 S#502        (CONST SURF SPEED)
M03            (SPINDLE ON)
G00 X33.0 Z[#501+2.0]
M08            (COOLANT ON)
G01 Z83.5 F0.1    (NOTCH FOR RING)
G01 X35.0 F0.1
#507=66.0          (START POINT OF FIRST GROOVE)
G01 Z[#507+8.0] F0.1
G01 X#514 Z[#507+6.5] F0.1
G01 Z[#507+1.5] F0.1
G01 X35.0 Z#507 F0.1
#507=52.5          (START POINT OF SECOND
GROOVE)
G01 Z[#507+8.0] F0.1
G01 X#514 Z[#507+6.5] F0.1
G01 Z[#507+1.5] F0.1
G01 X35.0 Z#507 F0.1
#507=39.0          (START POINT OF THIRD GROOVE)
G01 Z[#507+8.0] F0.1
G01 X#514 Z[#507+6.5] F0.1
G01 Z[#507+1.5] F0.1
G01 X35.0 Z#507 F0.1
#507=25.5        (START POINT OF FOURTH GROOVE)
G01 Z[#507+8.0] F0.1
G01 X#514 Z[#507+6.5] F0.1
G01 Z[#507+1.5] F0.1
G01 X35.0 Z#507 F0.1
#507=12.0          (START POINT OF FIFTH GROOVE)
G01 Z[#507+8.0] F0.1
G01 X#514 Z[#507+6.5] F0.1
G01 Z[#507+1.5] F0.1
G01 X35.0 Z#507 F0.1
;
G01 Z1.75 F0.1      (BACK CHAMFER)
G01 X31.3 Z-0.7 F0.1
G01 Z-3.0 F0.1
G01 X[#500+5.0] F2.0
M09           (COOLANT OFF)
M05           (SPINDLE OFF)
G28 U0 W0       (GO HOME)
M01           (OPTIONAL STOP)
;
;(CUTOFF)
;
N10
G28 U0 W0        (GOING HOME - JUST TO MAKE
SURE)
G00 T1010
G00 X[#500 + 2.0] Z-3.0
G50 S1000
G96 S#502
M03            (SPINDLE ON)
M08            (COOLANT ON)
G01 X-0.4 F.05     (CUTOFF)
G01 X[#500 + 2] F4.0  (RETRACT)
M09            (COOLANT OFF)
M05            (SPINDLE OFF)
G28 U0 W0        (GO HOME)
M30            (FINISH)
```

**Assembly motor bracket G Code**

```
O0225
(P:\ENGR 480
Manufacturing\assembly_motor_bracket.ncl.3)
(05/04/10-15:52:07)
G54
N0010T3M06
S1400M03
G00X2.5085Y.7125
G43Z.1H03M08
G01Z-.05F5.
X2.7415
G03X3.0572Y.91I-.1165J.5375
G01X2.1928
G02X2.0938Y1.1075I.4322J.34
G01X3.1562
G03X3.175Y1.25I-.5312J.1425
G01X3.1722Y1.305
X2.0778
G02X2.1365Y1.5025I.5472J-.055
G01X3.1136
G03X2.9411Y1.7I-.4886J-.2525
G01X2.3089
G03X2.3089Y1.7I.3161J-.45
X2.3088Y1.7I.3161J-.45
G01Z-.1
X2.9411
G02X3.1136Y1.5025I-.3161J-.45
G01X2.1364
G03X2.0778Y1.305I.4886J-.2525
G01X3.1722
X3.175Y1.25
G02X3.1562Y1.1075I-.55J0.
G01X2.0938
G03X2.1928Y.91I.5312J.1425
G01X3.0572
G02X2.7415Y.7125I-.4322J.34
G01X2.5085
G03X2.5085Y.7125I.1165J.5375
G01Z-.15
X2.7415
G03X3.0572Y.91I-.1165J.5375
G01X2.1928
G02X2.0938Y1.1075I.4322J.34
G01X3.1562
G03X3.175Y1.25I-.5312J.1425
G01X3.1722Y1.305
X2.0778
G02X2.1365Y1.5025I.5472J-.055
G01X3.1136
G03X2.9411Y1.7I-.4886J-.2525
G01X2.3089
G03X2.3089Y1.7I.3161J-.45
X2.3088Y1.7I.3161J-.45
G01Z-.2
X2.9411
G02X3.1136Y1.5025I-.3161J-.45
G01X2.1364
G03X2.0778Y1.305I.4886J-.2525
G01X3.1722
X3.175Y1.25
G02X3.1562Y1.1075I-.55J0.
G01X2.0938
G03X2.1928Y.91I.5312J.1425
G01X3.0572
G02X2.7415Y.7125I-.4322J.34
G01X2.5085
G03X2.5085Y.7125I.1165J.5375
G01Z-.25
X2.7415
G03X3.0572Y.91I-.1165J.5375
G01X2.1928
G02X2.0938Y1.1075I.4322J.34
G01X3.1562
G03X3.175Y1.25I-.5312J.1425
G01X3.1722Y1.305
X2.0778
G02X2.1365Y1.5025I.5472J-.055
G01X3.1136
G03X2.9411Y1.7I-.4886J-.2525
G01X2.3089
G03X2.3089Y1.7I.3161J-.45
X2.3088Y1.7I.3161J-.45
G01Z-.26
X2.9411
G02X3.1136Y1.5025I-.3161J-.45
G01X2.1364
```

**Snap Ring Feeder G-Code**

Below is the G Code to machine the trough. To get the necessary depth, this code was run twice, with the second process using the bottom of the trough as the new reference plane.

```
%
O0027
( 480 Manufacturing\snapringslide.ncl.2)
(06/01/10-10:59:48)
G54
N0010T3M06
S1100M03
G00X.75Y.5125
G43Z.1H03
G01Z-.03F5.
X5.75
Y.7042
X.4789
G02X.4789Y.8958I.2711J.0958
G01X5.75
Y1.0875
X.75
G03X.75Y.5125I0.J-.2875
G01X5.75
Y1.0875
X.75
Z-.05
X5.75
Y.8958
X.4789
G03X.4789Y.7042I.2711J-.0958
G01X5.75
Y.5125
X.75
X5.75
Y1.0875
X.75
G03X.75Y.5125I0.J-.2875
G01Z.1
N0020T6M06
S1800M03
G00X.4966Y.0625
G43Z.1H06
G01Z-.05F1.
X1.0034
Y.1068
X.4966
Y.1511
X1.0034
Y.1954
X.4966
Y.2397
X1.0034
Y.284
X.4966
Y.3283
X1.0034
Y.3652
G03X.9959Y.3727I-.0075J0.
G01X.5041
G03X.4966Y.3652I0.J-.0075
G01Y.0625
X1.0034
Y.3652
G03X.9959Y.3727I-.0075J0.
G01X.5041
Z-.1
X.9959
G02X1.0034Y.3652I0.J-.0075
G01Y.3283
X.4966
Y.284
X1.0034
Y.2397
X.4966
Y.1954
X1.0034
Y.1511
X.4966
Y.1068
X1.0034
Y.0625
X.4966
X1.0034
Y.3652
G03X.9959Y.3727I-.0075J0.
G01X.5041
G03X.4966Y.3652I0.J-.0075
G01Y.0625
Z-.15
X1.0034
Y.1068
X.4966
Y.1511
X1.0034
Y.1954
X.4966
Y.2397
X1.0034
Y.284
X.4966
Y.3283
X1.0034
Y.3652
G03X.9959Y.3727I-.0075J0.
G01X.5041
```

G03X.4966Y.3652I0.J-.0075
G01Y.0625
X1.0034
Y.3652
G03X.9959Y.3727I-.0075J0.
G01X.5041
Z-.2
X.9959
G02X1.0034Y.3652I0.J-.0075
G01Y.3283
X.4966
Y.284
X1.0034
Y.2397
X.4966
Y.1954
X1.0034
Y.1511
X.4966
Y.1068
X1.0034
Y.0625
X.4966
X1.0034
Y.3652
G03X.9959Y.3727I-.0075J0.
G01X.5041
G03X.4966Y.3652I0.J-.0075
G01Y.0625
Z-.25
X1.0034
Y.1068
X.4966
Y.1511
X1.0034
Y.1954
X.4966
Y.2397
X1.0034
Y.284
X.4966
Y.3283
X1.0034
Y.3652
G03X.9959Y.3727I-.0075J0.
G01X.5041
G03X.4966Y.3652I0.J-.0075
G01Y.0625
X1.0034
Y.3652
G03X.9959Y.3727I-.0075J0.
G01X.5041
Z-.3
X.9959
G02X1.0034Y.3652I0.J-.0075
G01Y.3283
X.4966
Y.284
X1.0034
Y.2397
X.4966
Y.1954
X1.0034
Y.1511
X.4966
Y.1068
X1.0034
Y.0625
X.4966
X1.0034
Y.3652
G03X.9959Y.3727I-.0075J0.
G01X.5041
G03X.4966Y.3652I0.J-.0075
G01Y.0625
Z-.35
X1.0034
Y.1068
X.4966
Y.1511
X1.0034
Y.1954
X.4966
Y.2397
X1.0034
Y.284
X.4966
Y.3283
X1.0034
Y.3652
G03X.9959Y.3727I-.0075J0.
G01X.5041
G03X.4966Y.3652I0.J-.0075
G01Y.0625
X1.0034
Y.3652
G03X.9959Y.3727I-.0075J0.
G01X.5041
Z-.4
X.9959
G02X1.0034Y.3652I0.J-.0075
G01Y.3283

```
X.4966
Y.284
X1.0034
Y.2397
X.4966
Y.1954
X1.0034
Y.1511
X.4966
Y.1068
X1.0034
Y.0625
X.4966
X1.0034
Y.3652
G03X.9959Y.3727I-.0075J0.
G01X.5041
G03X.4966Y.3652I0.J-.0075
G01Y.0625
Z.1
M30
%
```

**Large O-ring Positioning Cone G-Code**

```
O1
; (BIG ORING PLACER)
; (DAVID ROBBINS)
; (STOCK- 38.1 X 24.0 + 10MM)
; (TOOLS USED- CUTOFF 10, 80DEG ROUGH 01,
35DEG FINISH 02, CENTER PILOT 05)
;
; (VARIABLES)
#500=38.1          (STOCK DIA)
#501=10.0          (STOCK LENGTH)
#502=75.0          (ROUGH SURFACE SPEED, M/MIN)
#503=0.2           (ROUGH FEEDRATE, MM/REV)
#504=185.0         (FINISH SURFACE SPEED, M/MIN)
#505=0.03          (FINISH FEEDRATE, MM/REV)
;
G54
G21
M01      (OPTIONAL STOP TO GATHER VARIABLES)
;
; (FACING)
N1
G28 U0 W0
G00 T1010
G96 S#502                  (CONST SURFACE SPEED)
G50 S2000                  (LIMIT RPM)
G99                        (FEED PER REV)
G00 X[#500+2.0] Z#501      (SP)
M03                        (SPINDLE CCW)
M08                        (COOLANT)
G01 X-1.0 F#503
G01 X[#500+2.0]            (SP)
M09                        (COOLANT OFF)
M05                        (SPINDLE OFF)
G28 U0 W0
M01
;
; (ROUGH OD)
N2
G00 T0101
G96 S#502
G50 S2000
G99
G00 X[#500+2.0] Z[#501+1.0]      (SP)
M03                              (SPINDLE CCW)
M08                              (COOLANT)
G71 U1.0 R0.5
G71 P10 Q20 U1.0 W0.5 F#503
N10 G01 X16.0 Z11.0
   G01 X28.0 Z5.0
   G01 X29.0 Z4.5
   G01 X29.5 Z4.0
   G01 X30.0 Z2.5
N20 G01 X30.0 Z-1.5
G01 X[#500+2.0] Z[#501+1.0]      (SP)
M09                              (COOLANT OFF)
M05                              (SPINDLE OFF)
G28 U0 W0
M01
;
; (FINISH OD)
N3
G00 T0202
G96 S#504
G50 S2000
G99
G00 X[#500+2.0] Z[#501+1.0]      (SP)
M03                              (SPINDLE CCW)
M08                              (COOLANT)
G70 P10 Q20 F#505                (FINISH)
G01 X[#500+2.0] Z[#501+1.0]      (SP)
M09                              (COOLANT OFF)
M05                              (SPINDLE OFF)
G28 U0 W0
M01
;
; (CENTER PILOT)
N4
G00 T0505
G97 S1500
G99
G00 X0.0 Z[#501+1.0]       (SP)
M03                        (SPINDLE CCW)
M08                        (COOLANT)
G01 Z[#501-5.0] F#505      (CUT)
G01 Z[#501+1.0]  F1.0      (SP)
M09                        (COOLANT OFF)
M05                        (SPINDLE OFF)
G28 U0 W0
M01
;
; (CUTOFF)
N5
G00 T1010
G96 S#502
G50 S2000
G99
G00 X[#500+2.0] Z-3.0      (SP)
M03                        (SPINDLE CCW)
M08                        (COOLANT)
G01 X-1.5 F#503
G01 X[#500+2.0]            (SP)
M09                        (COOLANT OFF)
M05                        (SPINDLE OFF)
G28 U0 W0
```

```
M30
%
```

Base:

```
O1
; (BIG ORING PLACER PT 2)
; (DAVID ROBBINS)
; (STOCK- 38.1 X 7.2 + 10MM)
; (TOOLS USED- CUTOFF 10, 35 DEG FINISH 02,
CENTER PILOT 05, 18.7MM END MILL 07, 14.5MM
BORING BAR)
;
; (VARIABLES)
#500=38.1          (STOCK DIA)
#501=7.2           (STOCK LENGTH)
#502=75.0          (ROUGH SURFACE SPEED, M/MIN)
#503=0.2           (ROUGH FEEDRATE, MM/REV)
#504=185.0         (FINISH SURFACE SPEED, M/MIN)
#505=0.05          (FINISH FEEDRATE, MM/REV)
;
G54
G21
M01      (OPTIONAL STOP TO GATHER VARIABLES)
;
; (FACING)
N1
G28 U0 W0
G00 T1010
G96 S#502                  (CONST SURFACE SPEED)
G50 S2000                  (LIMIT RPM)
G99                        (FEED PER REV)
G00 X[#500+2.0] Z#501      (SP)
M03                        (SPINDLE CCW)
M08                        (COOLANT)
G01 X-1.0 F#503
G01 X[#500+2.0]            (SP)
M09                        (COOLANT OFF)
M05                        (SPINDLE OFF)
G28 U0 W0
M01
;
; (ROUGH ID WITH 18.7MM END MILL)
N2
G00 T0707
G96 S#502
G50 S2000
G99
G00 X18.7 Z[#501+1.0]      (SP)
M03                        (SPINDLE CCW)
M08                        (COOLANT)
G01 Z6.0 F#505
G01 X31.3
G01 Z[#501+1.0]            (SP)
M09                        (COOLANT OFF)
M05                        (SPINDLE OFF)
G28 U0 W0
M01
;
; (SHOULDER SHARPENING WITH 14.5MM BORING
BAR)
N3
G00 T0909
G96 S#502
G50 S2000
G99
G00 X14.6 Z[#501+1.0]      (SP)
M03                        (SPINDLE CCW)
M08                        (COOLANT)
G01 Z6.0 F#505
G01 X31.3
G01 Z[#501+1.0]            (SP)
M09                        (COOLANT OFF)
M05                        (SPINDLE OFF)
G28 U0 W0
M01
;
; (CENTER PILOT)
N4
G00 T0505
G97 S2000
G99
G00 X0.0 Z[#501+2.0]       (SP)
M03                        (SPINDLE CCW)
M08                        (COOLANT)
G01 Z[#501-7.0] F#503
G01 Z[#501+2.0] F1.0       (SP)
M09                        (COOLANT OFF)
M05                        (SPINDLE OFF)
G28 U0 W0
M01
;
; (FINISH OD)
N5
G00 T0202
G96 S#504
G50 S2000
G99
G00 X38.0 Z[#501+1.0]      (SP)
M03                        (SPINDLE CCW)
M08                        (COOLANT)
G01 Z-1.5 F#505
G01 X[#500+2.0]            (SP)
```

```
M09                     (COOLANT OFF)
M05                     (SPINDLE OFF)
G28 U0 W0
;
; (CUTOFF)
N6
G00 T1010
G96 S#502
G50 S2000
G99
G00 X[#500+2.0] Z-3.0   (SP)
M03                     (SPINDLE CCW)
M08                     (COOLANT)
G01 X-1.5 F#503
G01 X[#500+2.0]  F0.5   (SP)
M09                     (COOLANT OFF)
M05                     (SPINDLE OFF)
G28 U0 W0
M30
%
```

**Large O-ring Tool Outer Cone:**

```
O1
; (BIG ORING TOOL PT 2)
; (DAVID ROBBINS)
; (STOCK- 38.1 X 36.0 + 10MM)
; (TOOLS USED- CUTOFF 10, 80DEG ROUGH 01, 35 DEG FINISH 02, CENTER PILOT 05, 1/2 DEILL 12, 18.7MM END MILL 07)
;
; (VARIABLES)
#500=38.1          (STOCK DIA)
#501=36.0          (STOCK LENGTH)
#502=75.0          (ROUGH SURFACE SPEED, M/MIN)
#503=0.2           (ROUGH FEEDRATE, MM/REV)
#504=185.0         (FINISH SURFACE SPEED, M/MIN)
#505=0.05          (FINISH FEEDRATE, MM/REV)
;
G54
G21
M01      (OPTIONAL STOP TO GATHER VARIABLES)
;
; (FACING)
N1
G28 U0 W0
G00 T1010
G96 S#502                  (CONST SURFACE SPEED)
G50 S2000                  (LIMIT RPM)
G99                        (FEED PER REV)
G00 X[#500+2.0] Z#501      (SP)
M03                        (SPINDLE CCW)
M08                        (COOLANT)
G01 X-1.0 F#503
G01 X[#500+2.0]            (SP)
M09                        (COOLANT OFF)
M05                        (SPINDLE OFF)
G28 U0 W0
M01
;
; (CENTER PILOT)
N2
G00 T0505
G97 S2000
G99
G00 X0.0 Z[#501+2.0]       (SP)
M03                        (SPINDLE CCW)
M08                        (COOLANT)
G01 Z[#501-4.0] F#503
G01 Z[#501+2.0] F1.0       (SP)
M09                        (COOLANT OFF)
M05                        (SPINDLE OFF)
G28 U0 W0
M01
;
; (PECK DRILLING WITH 1/2 DRILL)
N3
G00 T1212
G97 S1200
G99
G00 X0.0 Z[#501+1.0]       (SP)
M03                        (SPINDLE CCW)
M08                        (COOLANT)
G01 Z[#501-5.0] F#503
G01 Z[#501+1.0] F1.0
G01 Z[#501-10.0] F#503
G01 Z[#501+1.0] F1.0
G01 Z[#501-15.0] F#503
G01 Z[#501+1.0] F1.0
G01 Z[#501-20.0] F#503
G01 Z[#501+1.0] F1.0
G01 Z[#501-25.0] F#503
G01 Z[#501+1.0] F1.0
G01 Z[#501-30.0] F#503
G01 Z[#501+1.0] F1.0
G01 Z-1.5 F#503
G01 Z[#501+1.0] F1.0       (SP)
M09                        (COOLANT OFF)
M05                        (SPINDLE OFF)
G28 U0 W0
M01
;
; (ROUGH ID WITH 18.7MM END MILL)
N4
G00 T0707
G96 S#502
G50 S2000
G99
G00 X18.7 Z[#501+1.0]      (SP)
M03                        (SPINDLE CCW)
M08                        (COOLANT)
G01 Z[#501-5.0] F#503      (DRILL)
G01 X31.0 F0.02
G04 F1.0
G01 X18.7 F#503
G01 Z[#501-10.0] (DRILL)
G01 X31.0 F0.02
G04 F1.0
G01 X18.7 F#503
G01 Z[#501-15.0] (DRILL)
G01 X31.0 F0.02
G04 F1.0
G01 X18.7 F#503
G01 Z[#501-20.0] (DRILL)
G01 X31.0 F0.02
G04 F1.0
G01 X18.7 F#503
```

```
G01 Z[#501-25.0] (DRILL)
G01 X31.0 F0.02
G04 X1.0
G01 X18.7 F#503
G01 Z[#501-30.0] (DRILL)
G01 X31.0 F0.02
G04 X1.0
G01 X18.7 F#503
G01 Z[#501-33.0] (DRILL)
G01 X31.0 F0.02
G04 F1.0
G01 X18.7 F#503
G01 Z-1.5                (DRILL)
G01 Z[#501+1.0]  F1.0    (SP)
G01 X31.6
G01 Z[#501-33.0] F#505   (FINISH ID)
G04 F1.0
G01 Z[#501+1.0] F1.0     (SP)
M09                      (COOLANT OFF)
M05                      (SPINDLE OFF)
G28 U0 W0
M01
;
; (ROUGH OD)
N5
G00 T0101
G96 S#502
G50 S2000
G99
G00 X37.5 Z[#501+1.0]    (SP)
M03                      (SPINDLE CCW)
M08                      (COOLANT)
G01 Z-1.5 F#503
G01 X[#500+2.0]          (SP)
M09                      (COOLANT OFF)
M05                      (SPINDLE OFF)
G28 U0 W0
M01
;
; (FINISH OD)
N6
G00 T0202
G96 S#504
G50 S2000
G99
G00 X37.0 Z[#501+1.0]    (SP)
M03                      (SPINDLE CCW)
M08                      (COOLANT)
G01 Z-1.5F#505
G01 X[#500+2.0]          (SP)
M09                      (COOLANT OFF)
M05                      (SPINDLE OFF)
G28 U0 W0
;
; (CUTOFF)
N7
G00 T1010
G96 S#502
G50 S2000
G99
G00 X[#500+2.0] Z-3.0    (SP)
M03                      (SPINDLE CCW)
M08                      (COOLANT)
G01 X-1.5
G01 X[#500+2.0]  F0.5    (SP)
M09                      (COOLANT OFF)
M05                      (SPINDLE OFF)
G28 U0 W0
M30
%
```

**Large O-ring Tool Inner Cylinder:**

```
O1
; (BIG ORING TOOL PT 1)
; (DAVID ROBBINS)
; (STOCK- 38.1 X 30.0 + 10MM)
; (TOOLS USED- CUTOFF 10, 80DEG ROUGH 01,
35DEG FINISH 02, CENTER PILOT 05, 1/2 DRILL 12,
18.7MM END MILL 07, 14.5MM BORING BAR 09)
;
; (VARIABLES)
#500=38.1          (STOCK DIA)
#501=30.0          (STOCK LENGTH)
#502=75.0          (ROUGH SURFACE SPEED, M/MIN)
#503=0.2           (ROUGH FEEDRATE, MM/REV)
#504=185.0         (FINISH SURFACE SPEED, M/MIN)
#505=0.05          (FINISH FEEDRATE, MM/REV)
;
G54
G21
M01      (OPTIONAL STOP TO GATHER VARIABLES)
;
; (FACING)
N1
G28 U0 W0
G00 T1010
G96 S#502                  (CONST SURFACE SPEED)
G50 S2000                  (LIMIT RPM)
G99                        (FEED PER REV)
G00 X[#500+2.0] Z#501      (SP)
M03                        (SPINDLE CCW)
M08                        (COOLANT)
G01 X-1.0 F#503
G01 X[#500+2.0]            (SP)
M09                        (COOLANT OFF)
M05                        (SPINDLE OFF)
G28 U0 W0
M01
;
; (PILOT)
N2
G00 T0505
G97 S2000
G99
G00 X0.0 Z[#501+1.0]       (SP)
M03                        (SPINDLE CCW)
M08                        (COOLANT)
G01 Z[#501-4.0] F#503
G01 Z[#501+1.0] F1.0       (SP)
M09                        (COOLANT OFF)
M05                        (SPINDLE OFF)
G28 U0 W0
M01
;
; (PECK DRILLING)
N3
G00 T1212
G97 S1200
G99
G00 X0.0 Z[#501+1.0]       (SP)
M03                        (SPINDLE CCW)
M08                        (COOLANT)
G01 Z[#501-5.0] F#503
G01 Z[#501+1.0] F1.0
G01 Z[#501-10.0] F#503
G01 Z[#501+1.0] F1.0
G01 Z[#501-15.0] F#503
G01 Z[#501+1.0] F1.0
G01 Z[#501-20.0] F#503
G01 Z[#501+1.0] F1.0
G01 Z[#501-26.0] F#503
G01 Z[#501+1.0] F1.0       (SP)
M09                        (COOLANT OFF)
M05                        (SPINDLE OFF)
G28 U0 W0
M01
;
; (ID MILLING)
N4
G00 T0707
G96 S#502
G50 S2000
G99
G00 X18.7 Z[#501+1.0]      (SP)
M03                        (SPINDLE CCW)
M08                        (COOLANT)
G01 Z[#501-6.2] F#503      (DRILL)
G01 X30.0 F0.02            (BITE)
G04 F1.0
G01 X18.7 F#503            (RECENTER)
G01 Z[#501-10.0] (DRILL)
G01 X29.0 F0.02            (BITE)
G04 F1.0
G01 X18.7 F#503            (RECENTER)
G01 Z[#501-15.0] (DRILL)
G01 X29.0 F0.02            (BITE)
G04 F1.0
G01 X18.7 F#503            (RECENTER)
G01 Z[#501-20.0] (DRILL)
G01 X29.0 F0.02            (BITE)
G04 F1.0
G01 X18.7 F#503            (RECENTER)
G01 Z[#501-25.0] (DRILL)
G01 X29.0 F0.02            (BITE)
G04 F1.0
```

```
G01 X18.7 Z[#501+2.0] F1.0          (SP)
M09                                 (COOLANT OFF)
M05                                 (SPINDLE OFF)
G28 U0 W0
M01
;
; (ID SHOULDER SHARPENING)
N5
G00 T0909
G96 S#502
G50 S2000
G99
G00 X15.0 Z[#501+1.0]               (SP)
M03                                 (SPINDLE CCW)
M08                                 (COOLANT)
G01 Z[#501-6.1] F0.5
G01 X30.0 F0.02
G01 Z[#501+1.0] F0.02               (SP)
M09                                 (COOLANT OFF)
M05                                 (SPINDLE OFF)
G28 U0 W0
M01
;
; (ROUGH OD)
N6
G00 T0101
G96 S#502
G50 S2000
G99
G00 X[#500+2.0] Z[#501+1.0]         (SP)
M03                                 (SPINDLE CCW)
M08                                 (COOLANT)
G71 U1.0 R0.5
G71 P10 Q20 U1.0 W0.5 F#503
N10 G01 X30.0 Z#501
   G01 X31.4 Z[#501-1.5]
N20 G01 X31.4 Z-1.5
G01 X[#500+2.0] Z[#501+1.0]         (SP)
M09                                 (COOLANT OFF)
M05                                 (SPINDLE OFF)
G28 U0 W0
M01
;
; (FINISH OD)
N7
G00 T0202
G96 S#504
G50 S2000
G99
G00 X[#500+2.0] Z[#501+1.0]         (SP)
M03                                 (SPINDLE CCW)
M08                                 (COOLANT)
G70 P10 Q20 F#505                   (FINISH)
G01 X[#500+2.0] Z[#501+1.0]         (SP)
M09                                 (COOLANT OFF)
M05                                 (SPINDLE OFF)
G28 U0 W0
M01
;
; (CUTOFF)
N8
G00 T1010
G96 S#502
G50 S2000
G99
G00 X[#500+2.0] Z-3.0               (SP)
M03                                 (SPINDLE CCW)
M08                                 (COOLANT)
G01 X-1.5
G01 X[#500+2.0]                     (SP)
M09                                 (COOLANT OFF)
M05                                 (SPINDLE OFF)
G28 U0 W0
M30
%
```

**Small O-ring Tool Sleeve:**

```
o1
; (DAVID ROBBINS)
; (SMALL O-RING TOOL, PART 2)
; (STOCK 38.1 X 20.0 + 10MM)
; (TOOLS USED - CUTOFF 10, 80DEG 01, 35DEG 02,
PILOT 05, 19/32" DRILL 12, 14.5MM BORING BAR 09)
;
; (VARIABLES)
#500=38.1          (STOCK DIA)
#501=14.2          (STOCK LENGTH)
#502=75.0          (ROUGH SURFACE SPEED, M/MIN)
#503=0.2           (ROUGH FEED RATE, MM/REV)
#504=185.0         (FINISH SURFACE SPEED, M/MIN)
#505=0.05          (FINISH FEED RATE, MM/REV)
;
G54
G99
G21
G50 S2000
;
; (FACING)
N1
G28 U0 W0
M01                (OPTIONAL STOP TO
GATHER VARIABLES)
G00 T1010          (CUTOFF TOOL)
G96 S#504
G50 S2000
G99
G00 X[#500+2.0] Z#501    (SP)
M03                (SPINDLE ON CCW)
M08                (COOLANT)
G01 X-1.0 F#503
G01 X[#500+2.0]  F0.5    (SP)
M09                (COOLANT OFF)
M05                (SPINDLE OFF)
G28 U0 W0
M01
;
; (ROUGH OD)
N2
G00 T0101          (55 DEG ROUGH CUT
TOOL)
G96 S#502          (CONST SURFACE SPEED)
G50 S2000          (LIMIT SPINDLE SPEED)
G99                (FEED PER REV MODE)
G00 X[#500+2.0] Z[#501+1.0]      (SP)
M03                (SPINDLE CCW)
M08                (COOLANT)
G71 U1.0 R0.5
G71 P10 Q20 U1.0 W0.5 F#503
N10 G01 X20.8 Z#501
N20 G01 X20.8 Z-1.5
G00 X[#500+2.0] Z[#501+1.0]      (SP)
M09                (COOLANT OFF)
M05                (SPINDLE OFF)
G28 U0 W0
M01
;
; (FINISH OD)
N3
G00 T0202          (OD FINISH TOOL)
G96 S#504          (CONSTANT SURFACE
SPEED)
G50 S2000          (LIMIT SPINDLE SPEED)
G99                (FEED PER REV MODE)
G00 X20.8 Z[#501+1.0]    (SP)
M03                (SPINDLE CCW)
M08                (COOLANT ON)
G01 X20.8 Z-1.5 F#505
G00 X[#500+2.0] Z[#501+1.0]      (SP)
M09                (COOLANT OFF)
M05                (SPINDLE OFF)
G28 U0 W0
M01
;
; (CENTER DRILL PILOT HOLE)
N4
T0505              (PILOT DRILL)
G97 S2000          (CONSTANT SPINDLE
SPEED)
G99
G00 X0.0 Z[#501+1.0]     (SP)
M03                (SPINDLE CCW)
M08                (COOLANT)
G01 Z[#501-3.0] F#503
G01 Z[#501+1.0] F1.0     (SP)
M09                (COOLANT OFF)
M05                (SPINDLE OFF)
G28 U0 W0
M01
;
; (PECK DRILLING WITH 19/32" DRILL)
N5
T1212
G97 S1200          (CONST SPINDLE SPEED)
G99                (FEED PER REV)
G00 X0.0 Z[#501+1.0]     (SP)
M03                (SPINDLE CCW)
M08                (COOLANT ON)
G01 Z[#501-5.0] F#503
G01 Z[#501+1.0] F1.0
G01 Z[#501-10.0] F#503
G01 Z[#501+1.0] F1.0
```

```
G01 Z[#501-14.0] F#503
G01 Z[#501+1.0] F1.0        (SP)
M09                         (COOLANT OFF)
M05                         (SPINDLE OFF)
G28 U0 W0                   (HOME)
M01
;
; (ID FINISH CYCLE WITH 14.5MM BORING BAR)
N6
T0909                       (14.5MM
BORING BAR)
G96 S#502                   (CONST SURFACE
SPEED)
G50 S2000                   (LIMIT SPINDLE
RPM)
G99                         (FEED PER REV
MODE)
M03                         (SPINDLE CCW)
M08                         (COOLANT)
G00 X15.1 Z[#501+1.0]       (SP)
G01 Z-1.5 F#503             (CUT)
G01 X15.0 Z[#501+1.0] F1.0  (RETRACT)
G01 X16.0                   (BITE)
G01 Z-1.5 F#503             (CUT)
G01 X15.5 Z[#501+1.0] F1.0  (RETRACT)
G01 X17.0                   (BITE)
G01 Z-1.5 F#503             (CUT)
G01 X16.5 Z[#501+1.0] F1.0  (RETRACT)
G01 X17.7                   (BITE)
G01 Z-1.5 F#503             (CUT)
G01 X17.3 Z[#501+1.0] F1.0  (RETRACT)
G01 X18.1                   (BITE)
G01 Z-1.5 F#505 S#504       (FINISH CUT)
G01 X15.0 Z[#501+1.0] F1.0  (SP)
M09                         (COOLANT OFF)
M05                         (SPINDLE OFF)
G28 U0 W0                   (HOME)
M01
; (CUTOFF)
N7
T1010                       (CUTOFF TOOL)
G96 S#502                   (CONST SURFACE SPEED)
G50 S2000                   (LIMIT SPINDLE RPM)
G99                         (FEED PER REV MODE)
G00 X[#500+2.0]  Z-3.0      (SP)
M03                         (SPINDLE CCW)
M08                         (COOLANT)
G01 X-1.5 F#503
G01 X[#500+2.0]             (SP)
M09                         (COOLANT OFF)
M05                         (SPINDLE OFF)
G28 U0 W0
M30
%
```

**Small O-ring Tool Inner Cylinder:**

```
O1
; (DAVID ROBBINS)
; (SMALL O-RING PICKER - PART 1)
; (STOCK 38.1 X 42.4 + 10MM)
; (AL CUTTING SPEED 75M/MIN ROUGH, 185 M/MIN
FINISH)
; (TOOLS USED- CUTOFF 10, 55DEG 01, 35DEG 02,
PILOT 05, 19/32" DRILL 12)
;
; (VARIABLES)
#500=38.1          (STOCK DIA)
#501=41.0          (STOCK LENGTH)
#502=75.0          (ROUGH SURFACE SPEED, M/MIN)
#503=0.2           (ROUGHING SPEED, MM/REV)
#504=0.05          (FINISH SPEED, MM/REV)
#505=185.0         (FINISH SURFACE SPEED, M/MIN)
;
G54
G21
M01                (OPTIONAL STOP TO GATHER
VARIABLES)
; (FACING)
N1
G28 U0 W0
G00 T1010                  (CUTOFF TOOL)
G96 S#502
G50 S2000
G99
G00 X[#500+2.0]  Z#501     (SP)
M03                        (SPINDLE CCW)
M08                        (COOLANT)
G01 X-1.0 F#503
G01 X[#500+2.0]            (SP)
M09                        (COOLANT OFF)
M05                        (SPINDLE OFF)
G28 U0 W0
M01
;
; (OD ROUGH CYCLE)
N2
G00 T0101                          (ROUGH CUT
TOOL)
G96 S#502
G50 S2000
G99
G00 X[#500+2.0] Z[#501+1.0]        (SP)
M03                                (SPINDLE CCW)
M08                                (COOLANT)
G71 U1.0 R0.5
G71 P10 Q20 U1.0 W0.5 F#503
N10 G01X19.0 Z#501
   G01    X20.0 Z[#501-1.0]
   G01 X20.0 Z7.0
   G01 X25.0 Z7.0
N20 G01X25.0 Z-1.5
G00 X[#500+2.0] Z[#501+1.0]        (SP)
M09                                (COOLANT OFF)
M05                                (SPINDLE OFF)
G28 U0 W0
M01
;
; (FINISH CYCLE WITH 35DEG FINISH TOOL)
N3
T0202                              (FINISH TOOL 02)
G96 S#505
G50 S2000
G99
G00 X[#500+2.0] Z[#501+1.0]        (SP)
M03                                (SPINDLE CCW)
M08                                (COOLANT)
G70 P10 Q20 F#504                  (OD FINISH
CYCLE)
G00 X[#500+2.0] Z[#501+1.0]        (SP)
M09                                (COOLANT OFF)
M05                                (SPINDLE OFF)
G28 U0 W0
M01
;
; (CENTER DRILL PILOT HOLE)
N4
G00 T0505                          (CENTER DRILL,
TOOL 05)
G97 S2000
G99
G00 X0.0 Z[#501+1.0]               (SP)
M03                                (SPINDLE CCW)
M08                                (COOLNAT)
G01 X0.0 Z[#501-4.0] F0.5 (CUT)
G01 X0.0 Z[#501+1.0] F1.0 (SP)
M09                                (COOLANT OFF)
M05                                (SPINDLE OFF)
G28 U0 W0
M01
;
; (PECK DRILLING WITH 19/32" DRILL)
N5
G00 T1212                (TOOL CHANGE TO 1/2"
DRILL)
G97 S1200
G99
G00 X0.0 Z[#501+1.0]     (SP)
M03                      (SPINDLE CCW)
M08                      (COOLANT)
```

```
G01 Z[#501-5.0] F#503      (CUT)
G01 Z[#501+1.0] F1.0       (RETRACT)
G01 Z[#501-10.0] F#503     (CUT)
G01 Z[#501+1.0] F1.0       (RETRACT)
G01 Z[#501-15.0] F#503     (CUT)
G01 Z[#501+1.0] F1.0       (RETRACT)
G01 Z[#501-20.0] F#503     (CUT)
G01 Z[#501+1.0] F1.0       (RETRACT)
G01 Z[#501-24.63] F#503    (CUT)
G04 F1.0            (DWELL)
G01 Z[#501+1.0] F1.0       (SP)
M09                        (COOLANT)
M05                        (SPINDLE OFF)
G28 U0 W0
M01
;
; (CUTOFF)
N8
G00 T1010
G96 S#502
G50 S2000
G99
G00 X[#500+2.0] Z-3.0      (SP)
M03                        (SPINDLE CCW)
M08                        (COOLANT)
G01 X-1.0 F#503
G01 X[#500+2.0]            (SP)
M09                        (COOLANT OFF)
M05                        (SPINDLE OFF)
G28 U0 W0
M30
%
```

**Snap-Ring Tool:**

```
o1
; (DAVID ROBBINS)
; (SNAP-RING TOOL)
; (STOCK - 38.1 X 20.8 + 10MM)
; (TOOLS USED - CUTOFF 10, 80DEG 01, 35DEG 02,
PILOT 05, 1/2" DRILL 12)
;
; (VARIABLES)
#500=38.1          (STOCK DIA)
#501=20.8          (STOCK LENGTH)
#502=75.0          (ROUGH SURFACE SPEED, M/MIN)
#503=0.2           (ROUGH FEED RATE, MM/REV)
#504=185.0         (FINISH SURFACE SPEED, M/MIN)
#505=0.05          (FINISH FEED RATE, MM/REV)
;
G54
G99
G21
G50 S2000
;
; (FACING)
N1
G28 U0 W0
M01                (OPTIONAL STOP TO
GATHER VARIABLES)
G00 T1010          (CUTOFF TOOL)
G96 S#502
G50 S2000
G99
G00 X[#500+2.0] Z#501    (SP)
M03                (SPINDLE ON CCW)
M08                (COOLANT)
G01 X-1.0 F#503
G01 X[#500+2.0]  F0.5    (SP)
M09                (COOLANT OFF)
M05                (SPINDLE OFF)
G28 U0 W0
M01
;
; (ROUGH CYCLE)
N2
G00 T0101          (80DEG ROUGH CUT
TOOL)
G96 S#502          (CONST SURFACE SPEED)
G50 S2000          (LIMIT SPINDLE SPEED)
G99                (FEED PER REV MODE)
G00 X[#500+2.0] Z[#501+1.0]      (SP)
M03                (SPINDLE CCW)
M08                (COOLANT)
G71 U1.0 R0.5
G71 P10 Q20 U1.0 W0.5 F#503
N10 G01 X18.0 Z#501 F#505
   G01 X18.85 Z[#501-0.8] F#505
   G01 X25.2 Z[#501-0.8] F#505
N20 G01 X20.8 Z-1.5 F#505
G00 X[#500+2.0] Z[#501+1.0]      (SP)
M09                (COOLANT OFF)
M05                (SPINDLE OFF)
G28 U0 W0
M01
;
; (FINISH OD)
N3
G00 T0202          (OD FINISH TOOL)
G96 S#504          (CONSTANT SURFACE
SPEED)
G50 S2000          (LIMIT SPINDLE SPEED)
G99                (FEED PER REV MODE)
G00 X[#500+2.0] Z[#501+1.0]      (SP)
M03                (SPINDLE CCW)
M08                (COOLANT ON)
G70 P10 Q20
G00 X[#500+2.0] Z[#501+1.0]      (SP)
M09                (COOLANT OFF)
M05                (SPINDLE OFF)
G28 U0 W0
M01
;
; (CENTER DRILL PILOT HOLE)
N4
T0505              (PILOT DRILL)
G97 S2000          (CONSTANT SPINDLE
SPEED)
G99
G00 X0.0 Z[#501+1.0]     (SP)
M03                (SPINDLE CCW)
M08                (COOLANT)
G01 Z[#501-3.0] F#503
G01 Z[#501+1.0] F1.0     (SP)
M09                (COOLANT OFF)
M05                (SPINDLE OFF)
G28 U0 W0
M01
;
; (PECK DRILLING WITH 1/2" DRILL)
N5
T1212
G97 S1200          (CONST SPINDLE SPEED)
G99                (FEED PER REV)
G00 X0.0 Z[#501+1.0]     (SP)
M03                (SPINDLE CCW)
M08                (COOLANT ON)
G01 Z[#501-5.0] F#503
```

```
G01 Z[#501+1.0] F1.0
G01 Z[#501-10.0] F#503
G01 Z[#501+1.0] F1.0
G01 Z[#501-15.0] F#503
G01 Z[#501+1.0] F1.0      (SP)
M09                       (COOLANT OFF)
M05                       (SPINDLE OFF)
G28 U0 W0                 (HOME)
M01
;
; (CUTOFF)
N6
T1010                     (CUTOFF TOOL)
G96 S#502                 (CONST SURFACE SPEED)
G50 S2000                 (LIMIT SPINDLE RPM)
G99                       (FEED PER REV MODE)
G00 X[#500+2.0]  Z-3.0    (SP)
M03                       (SPINDLE CCW)
M08                       (COOLANT)
G01 X-1.5 F#503
G01 X[#500+2.0]           (SP)
M09                       (COOLANT OFF)
M05                       (SPINDLE OFF)
G28 U0 W0
M30
```