

F24 Capstone Catheter Roller Robot

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Project Description

- Clients work in Bioengineering Devices Lab in treatment of clots and brain aneurysms in the circle of Willis
- Design, build, and test a robotic system that can translate and rotate a catheter into a benchtop vessel model remotely
- Allows testing of catheters in presence of x-rays
- Sponsor: Dr. Becker

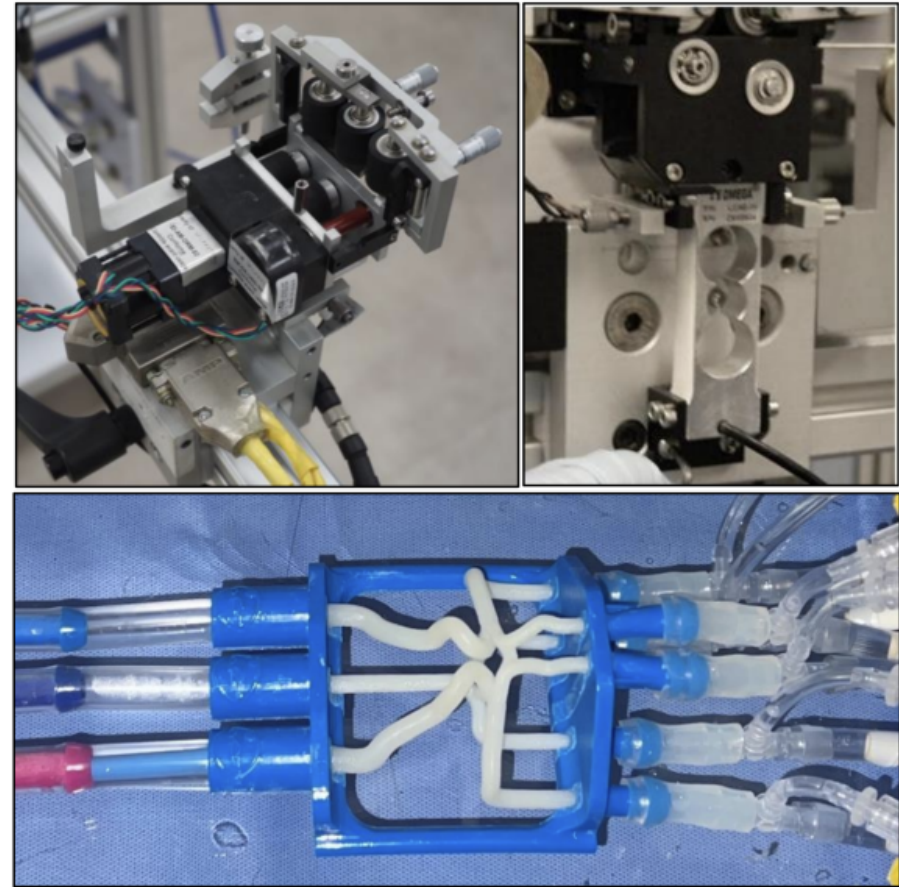


Figure 1. Top: Machine Solutions (MSI) IDTE Catheter Roller, Bottom: BDL Circle of Willis Model [1]

Customer Requirements

- Translation and rotation of catheter
- Pre-programmed or controlled remotely
- Measure data instantaneously
- Emergency stop system
- Level the introducer and system to prevent kinking
- Force measurement equipment easy to replace
- Mechanism to prevent load cell damage
- Easy to disassemble/reassemble, transport case
- Force and distance calibrations and testing

Engineering Requirements

- Translation of catheter at least 2 ft
- Rotation of catheter at least 360 degrees
- Remote controlled from at least 10 ft away
- Sampling rate frequency between 5-30 Hz
- Handle catheter sizes between 2-15 French
- Measure push resistance force between 0.1-10 N
- Measure displacement of catheter with resolution of at least 0.1 mm
- System noise/tolerance less than ± 0.05 N
- Total size under 1 cubic foot

Design Requirements

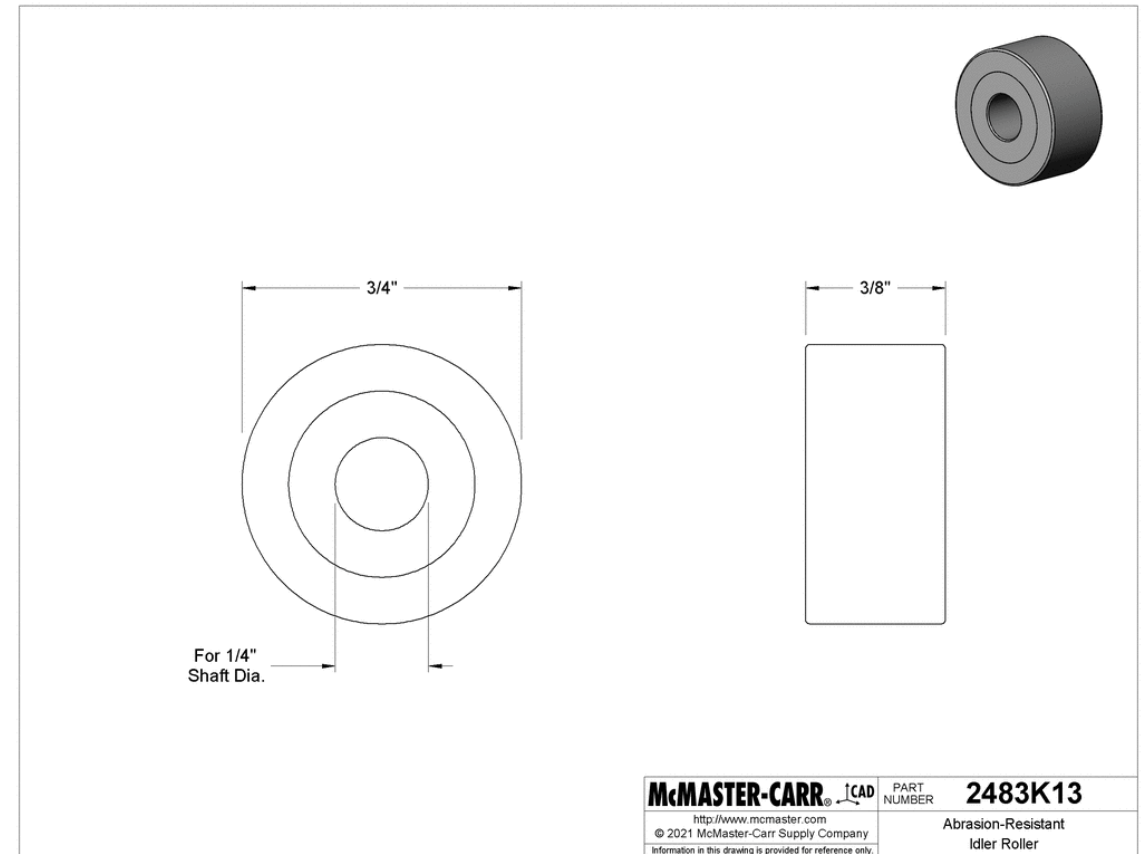
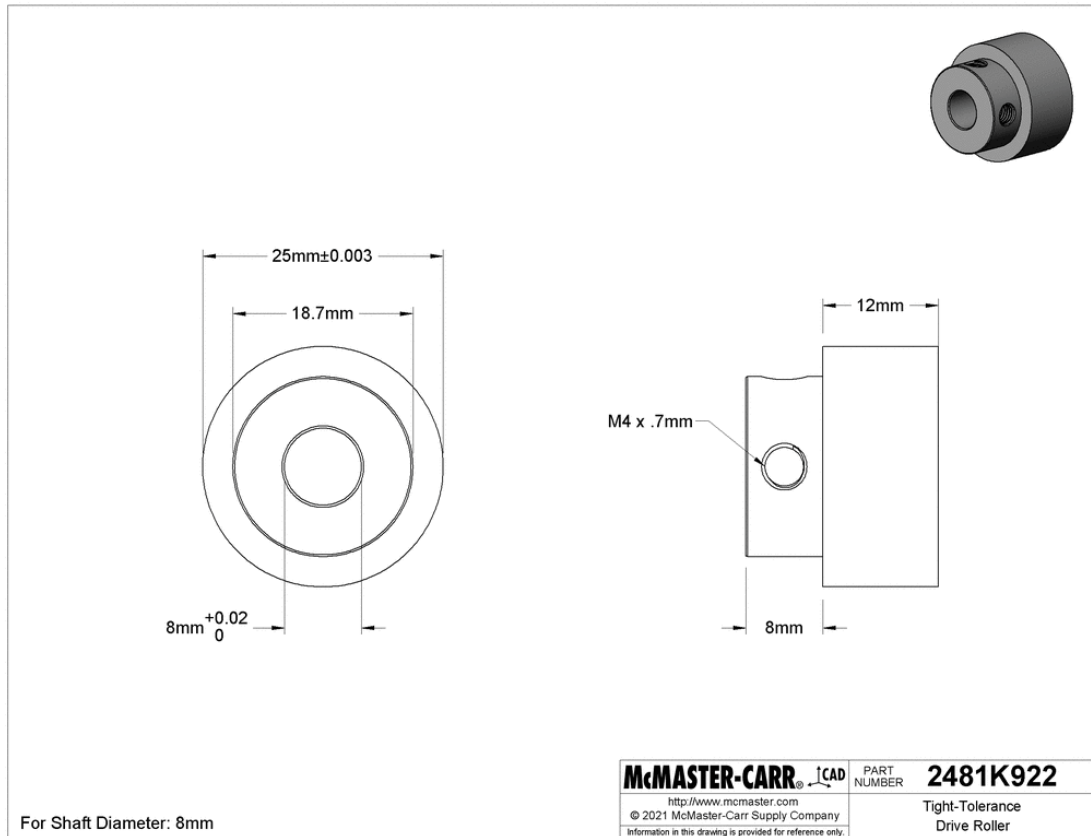
Translate catheter over distance									
Full rotation of catheter	3								
Controlled from a distance	1								
Fast sampling rate		3	3						
Handle variable diameters		1							
Measure push resistance	1			3	1				
Measure displacement resolution	9			3					
Low system noise/tolerance			1	9		3	3		
Limited volume	1		1			1	1		

Project title:	Catheter Roller
Project team:	F24toSp25_02
Date:	9/11/2024

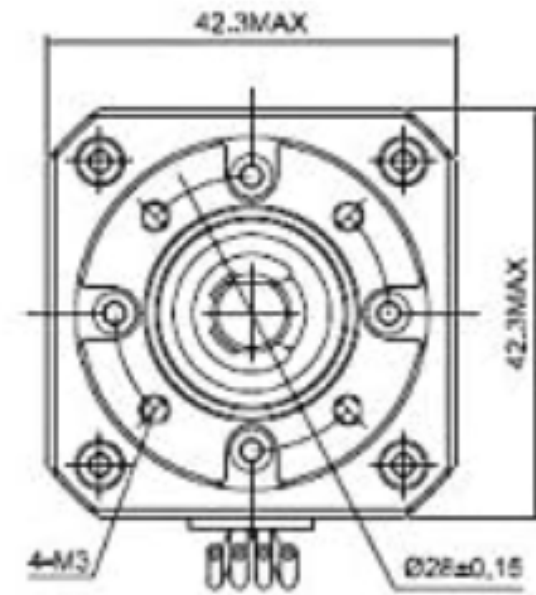
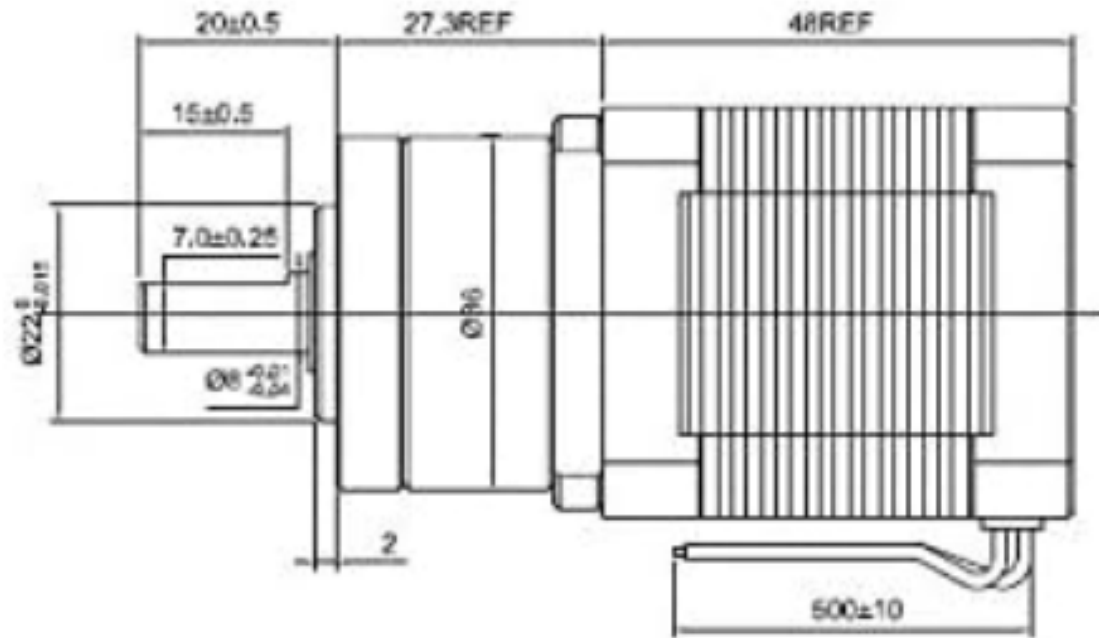
Design Requirements

Customer Needs	Customer Weights	Technical Requirements									Customer Opinion Survey				
		Translate catheter over distance	Full rotation of catheter	Controlled from a distance	Fast sampling rate	Handle variable diameters	Measure push resistance	Measure displacement resolution	Low system noise/tolerance	Limited volume	1 Poor	2	3 Acceptable	4	5 Excellent
Translation and rotation of catheter	1	9	9	1	3	3		9	3				A		B C
Pre-programmed or controlled remotely	1	3	3	9			1		3			A			B C
Measure data instantaneously	3	1	1		9	1	3	3	9						A C
Emergency stop system	2			3					1				C		A
Level introducer and system to prevent kinking	3						9								A
Force measurement equipment easy to replace	4						3		1				A		
Mechanism to prevent load cell damage	3				3		3		1					A	
Easy to disassemble/reassemble, transport case	5			1					9	A			C		B
Force and distance calibrations and testing	3	3	3		1	3	3	3					C		A
Technical Requirement Units		ft	degrees	ft	Samples/sec	F	lbf	in	lbf	ft ³	Legend	System name			
Technical Requirement Targets		2	360	10	5 to 30	2 to 15	0.0225-2.25	0.0034	0.0112	<1	A	MSI interventional device testing equipment 3000			
Absolute Technical Importance		1 24	2 24	3 21	7 42	4 15	6 67	5 27	8 38	9 49	B	Microbot Medical: Liberty Robot			
Relative Technical Importance		1	2	3	7	4	6	5	8	9	C	Catheter Navigation Using Haptic			

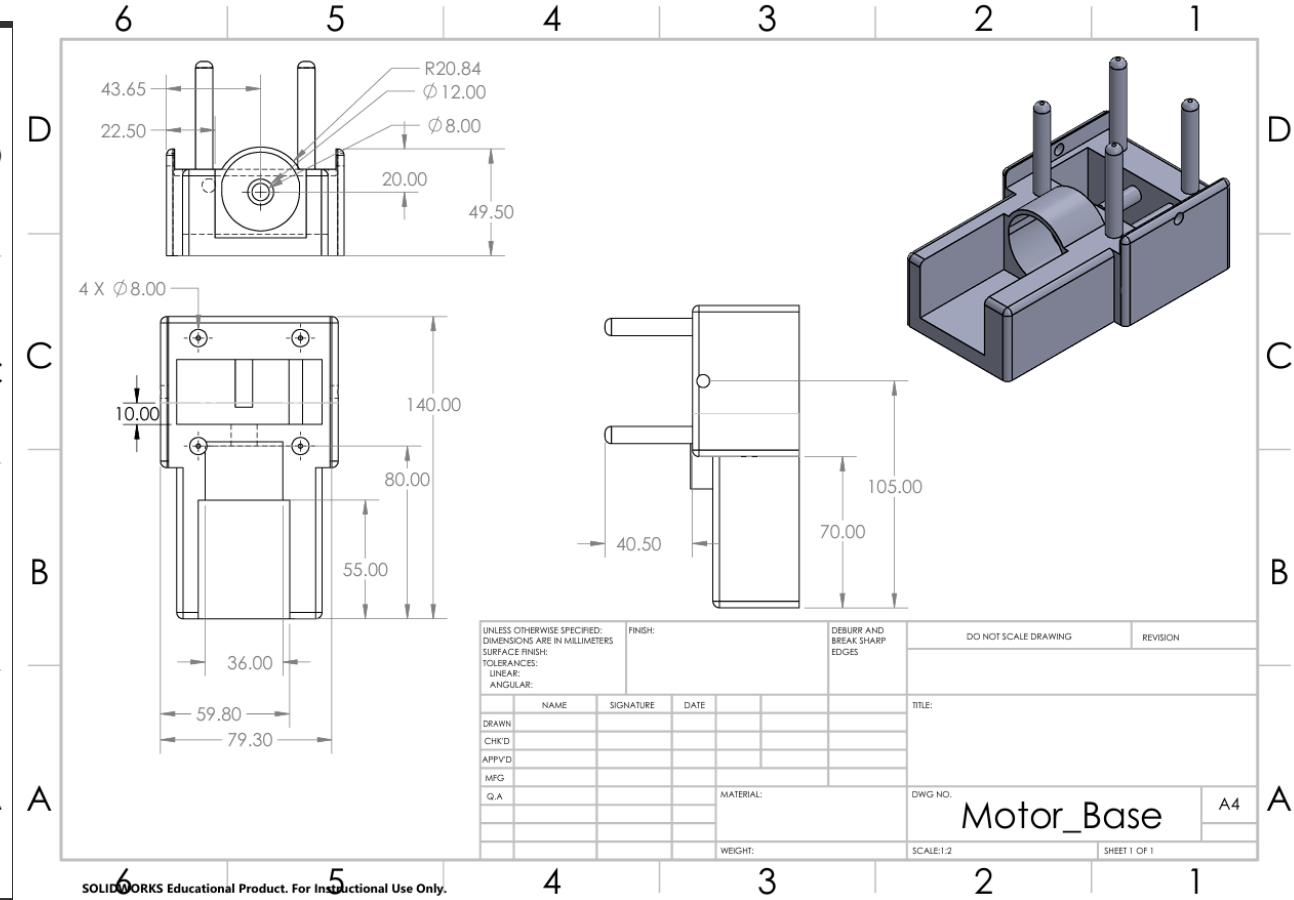
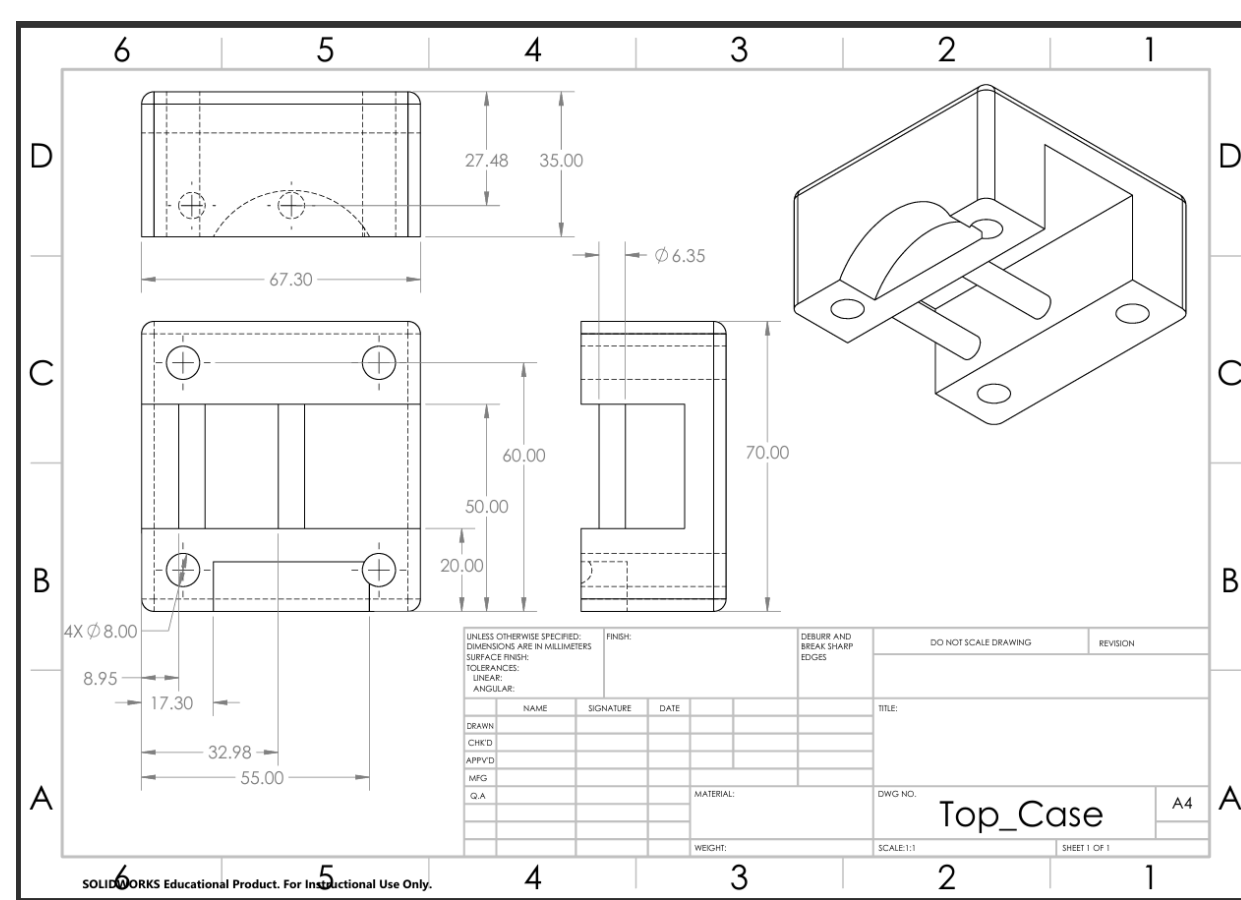
Design Description - Translation



Design Description - Translation



Design Description - Translation



Design Description - Translation

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Motor & Bottom Roller Case	Case for the motor and Bottom set of rollers	1
2	2481K922	Tight-Tolerance Drive Roller	1
3	2483K13	Abrasion-Resistant Idler Roller	3
4	Motor	Nema 17 5:1 Planetary motor	1
5	Top Roller Case	Case for top set of rollers	1
6	Driver Shaft	Extension for motor shaft	1
7	Idle Shaft	Metal shaft for idler rollers	3

UNLESS OTHERWISE SPECIFIED:
 DIMENSIONS ARE IN MILLIMETERS
 SURFACE FINISH: FRESH
 TOLERANCES: LINEAR: ANGULAR:

DEBurr AND BREAK SHARP EDGES

DO NOT SCALE DRAWING

REVISION

NAME: _____ SIGNATURE: _____ DATE: _____

TITLE: _____

DRAWN: _____ CHECKED: _____ APPROVED: _____

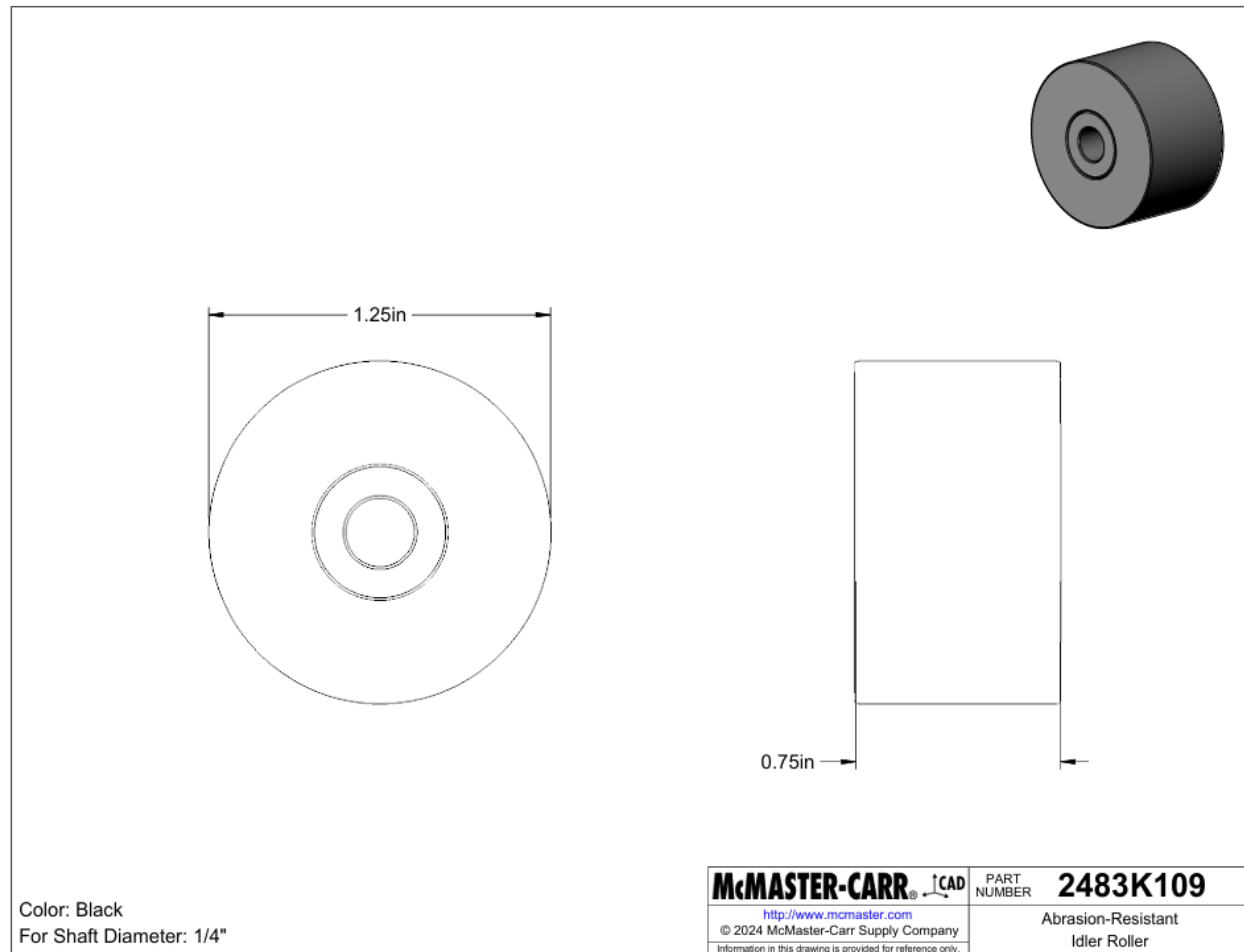
MFG: _____ Q.A.:

MATERIAL: _____ DWG NO: Full Assembly A3

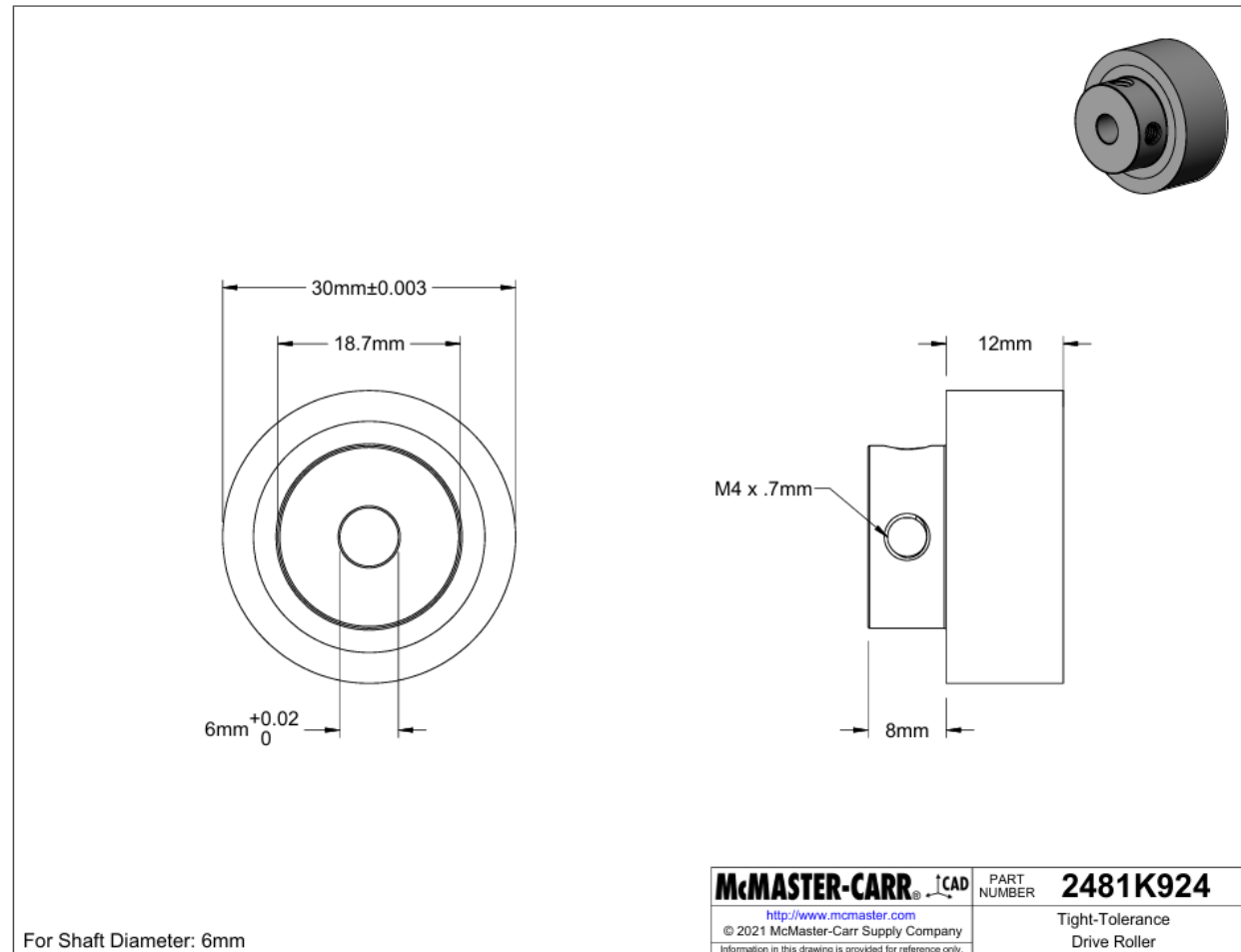
WEIGHT: _____ SCALE: 1:2 SHEET 1 OF 1

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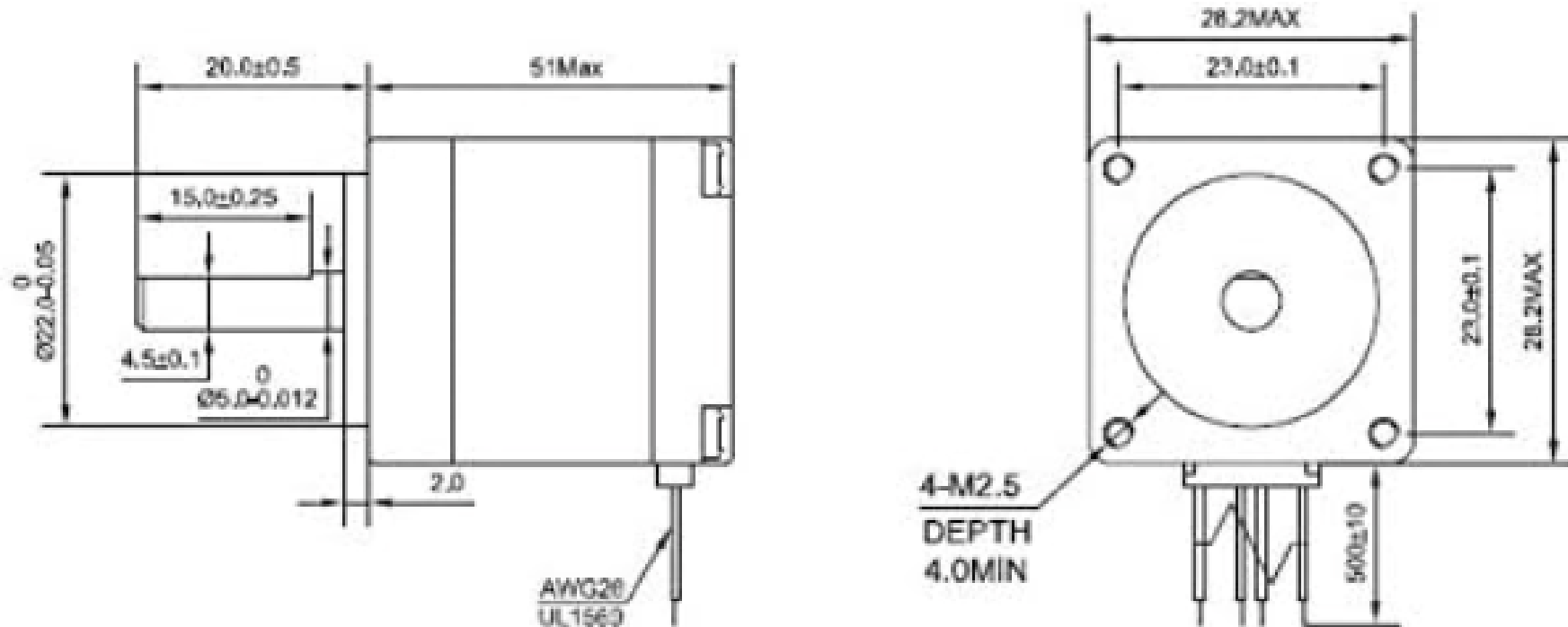
Design Description - Rotation



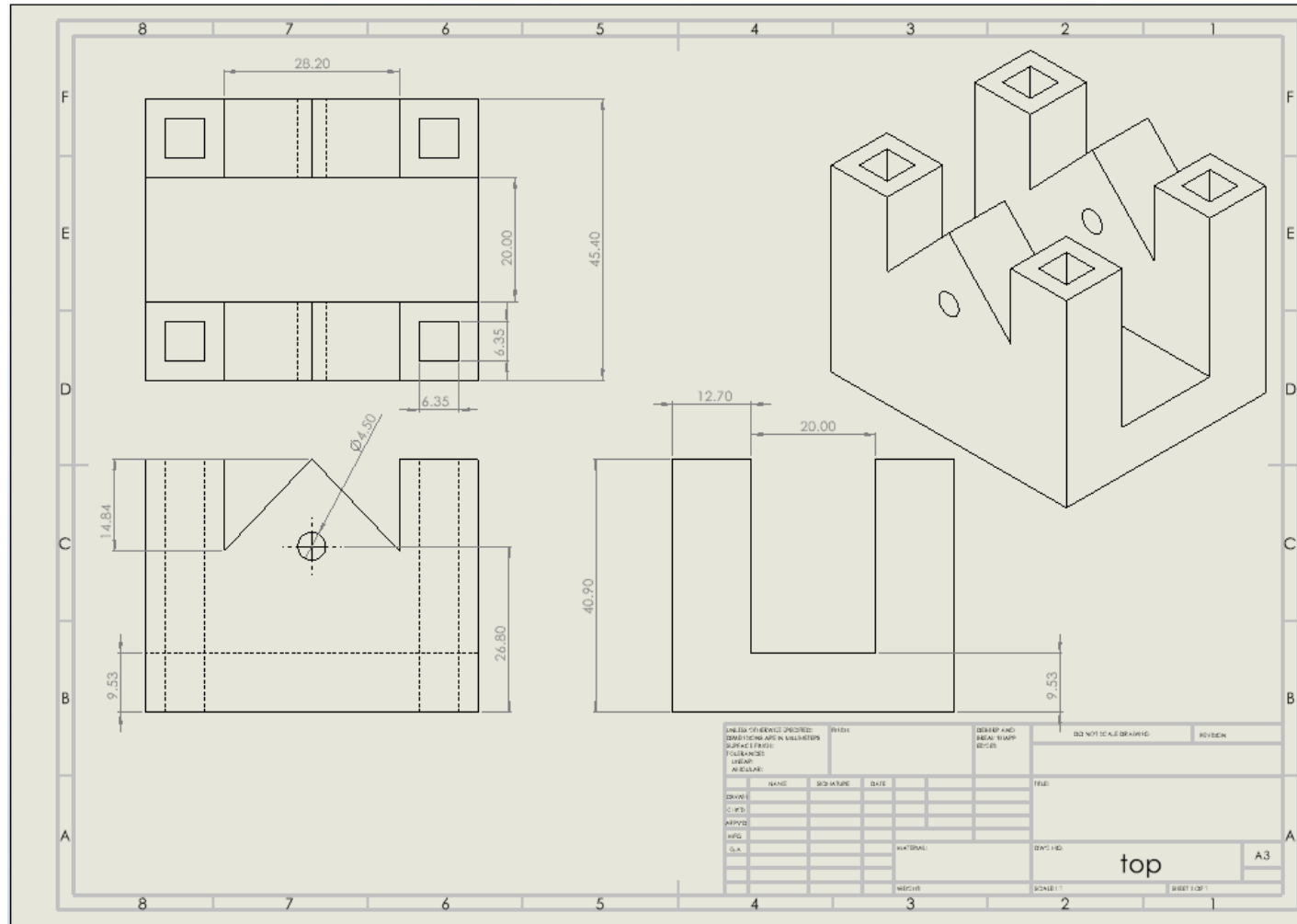
Design Description - Rotation



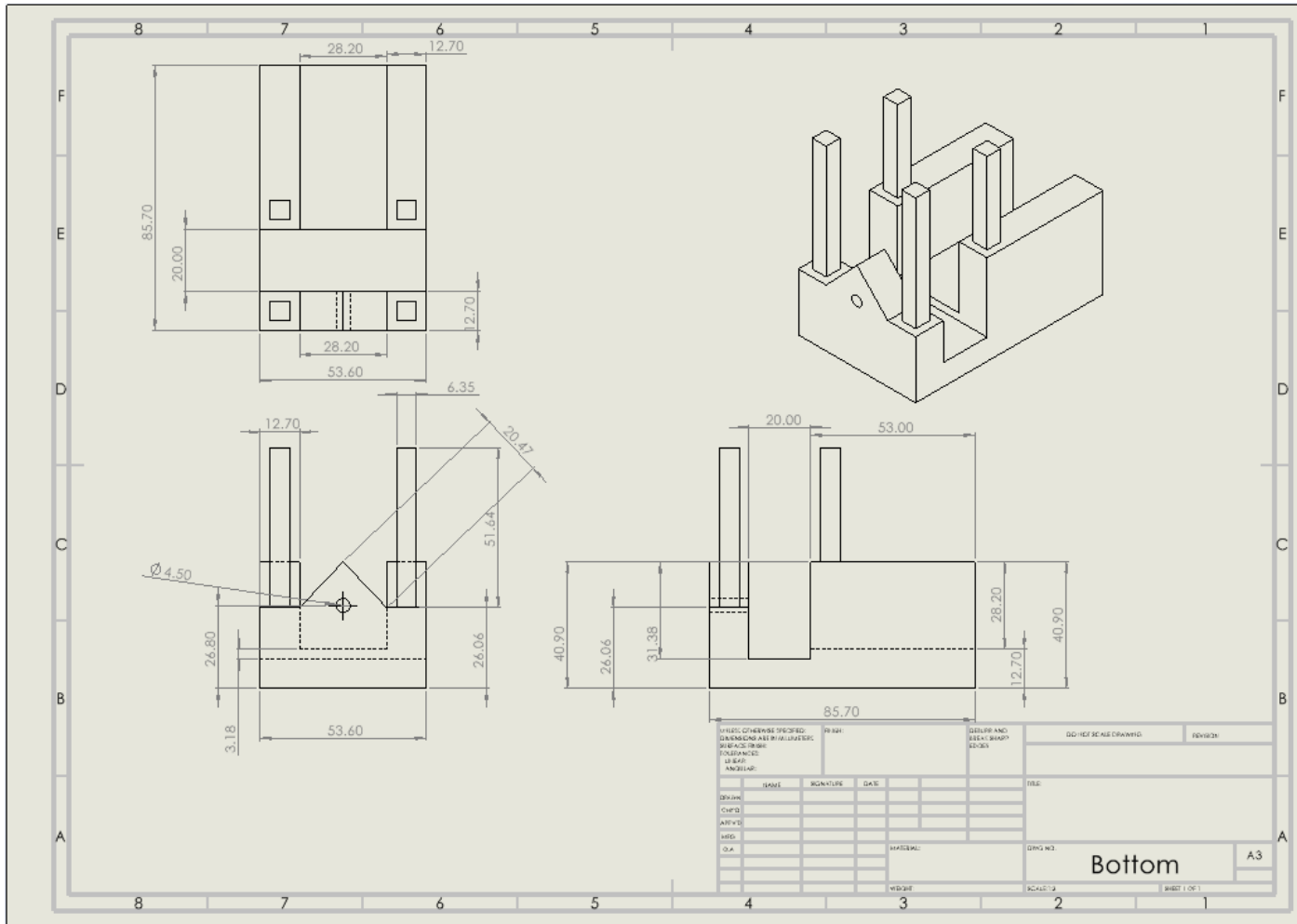
Design Description - Rotation



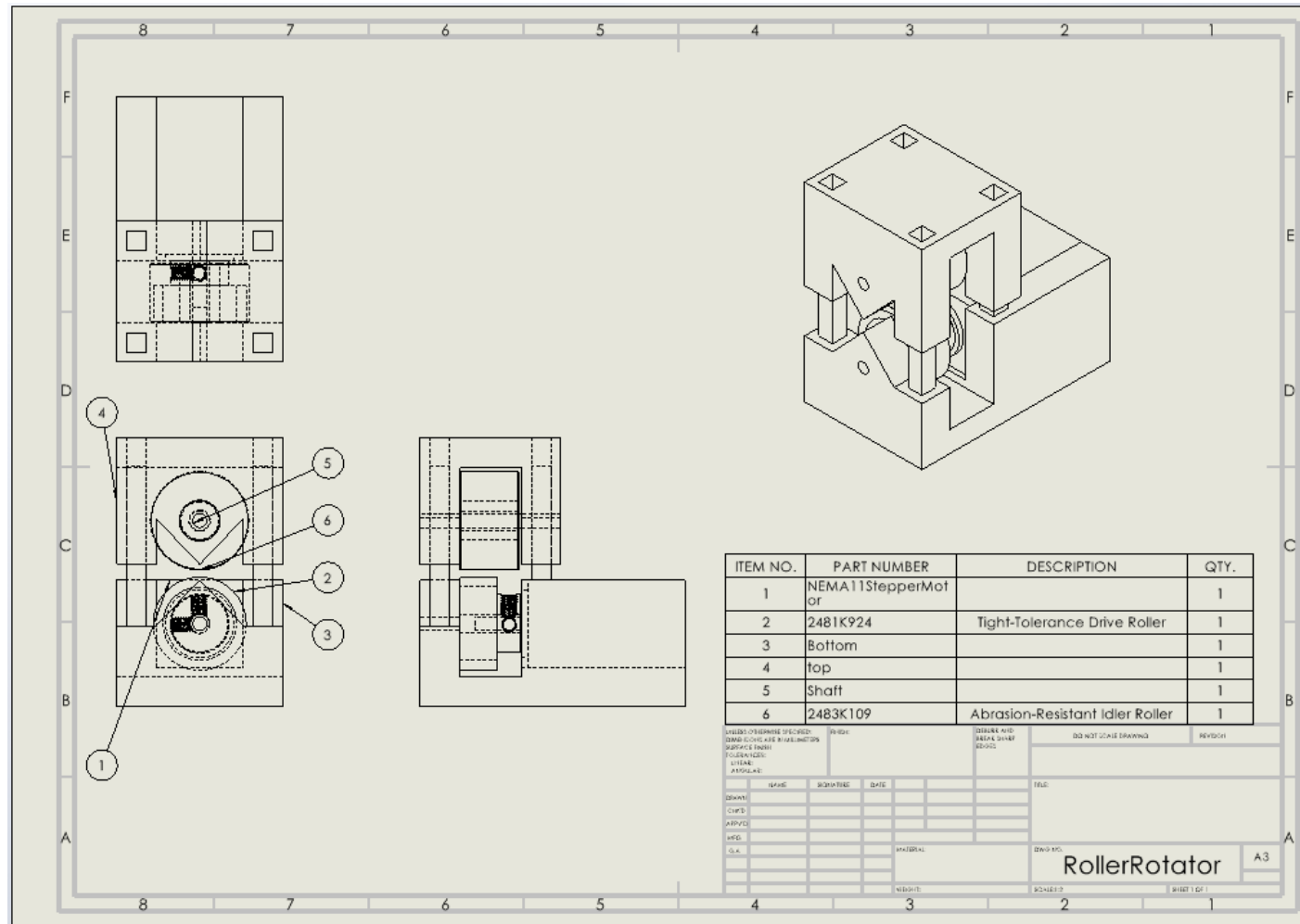
Design Description - Rotation



Design Description - Rotation



Design Description - Rotation



Engineering Calculations

Translation Component Motor Selection:

Nema 17 5:1 planetary gear w/ 25mm drive roller

$$S = r * ((\pi)/180) * \text{deg.}$$

Direct Drive: 0.39mm/step > 0.1mm/step

$0.39/0.1 = 3.9:1 = 4:1$ gives 0.098mm/step

5:1 gear ratio: 0.079mm/step GOOD

Rotation Component Motor Selection:

Nema 11 w/ 30 mm drive roller

Need: 360 (deg) of motion

Aim for: 0.5 (deg)/step

Smallest catheter: 0.7 mm

Ratio: $30/0.7 = 1:43$

$0.5/43 = 0.012$ (deg)/step

$1.8/0.012 = 150$ sub step

128 sub step closest

$1.8/128 = 0.014$ (deg)/step

$0.014 * 43 = 0.6$ (deg)/step GOOD

Engineering Calculations

NEMA 17: 2.8 V, 1.68 A

Driver: A4988

8 – 35 V, 2 A.

$V_{REF} = I_{MAX}(8 \cdot R_{CS})$

For full step $I_{MAX} * 1.4$ (40% higher)

$I_{MAX} = 1.68 * 1.4 = 2.4 \text{ A}$ (20% > rated)

$V_{REF} = 2.4(8 \cdot 0.068) = 1.3 \text{ V}$

NEMA 11: 6.2 V, 0.68 A

Driver: DVR8434

4.5 V – 48 V, 2A

$V_{REF} = I_{MAX} * 1.32$

$V_{REF} = 0.68 * 1.32 = 0.90 \text{ V}$

Default: 128 sub step

$I = 0.88 + 0.98 + 0.5 = 2.36 \text{ A}$ | Power Supply: 12 V 2.36 A

PE = 0.8

Arduino: 12 V input 500mA

Nema 11: $P = I * V * 2$

$P = 6.2 * 0.68 * 2 = 8.4 \text{ W}$

$8.4 / 0.8 = 10.5 \text{ W}$

$I = P/V \rightarrow 10.5/12 = 0.88 \text{ A}$

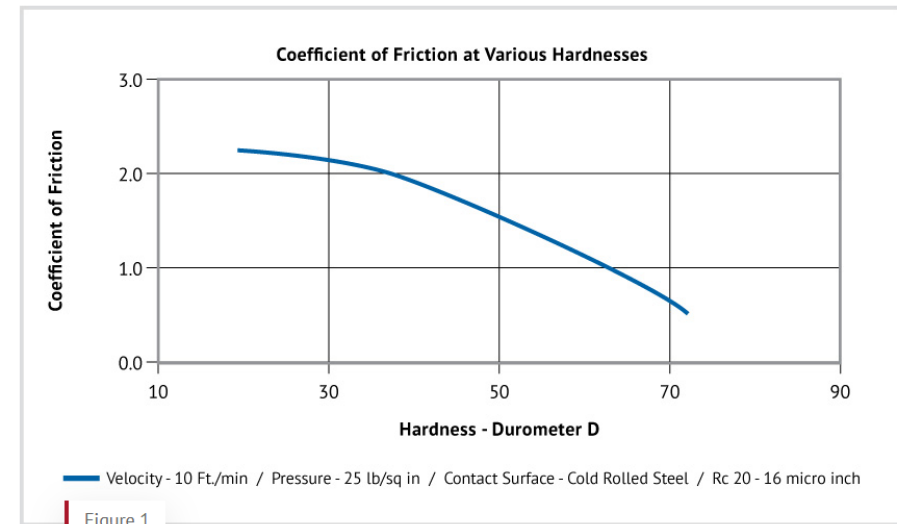
Nema 17: $P = 2.8 * 1.68 * 2 = 9.4 \text{ W}$

$9.4 / 0.8 = 11.8 \text{ W}$

$I = 11.8/12 = 0.98 \text{ A}$

Engineering Calculations

- Idle rollers were selected at $\frac{3}{4}$ "(19.05mm)
- Material chosen for the rollers is urethane rubber with a hardness of 55A
- Selected because:
 - Abrasion resistant
 - Absorbent to vibrations
 - High stress resistance
 - Hardness high enough to grip catheter



Coefficient of friction for urethane[2]

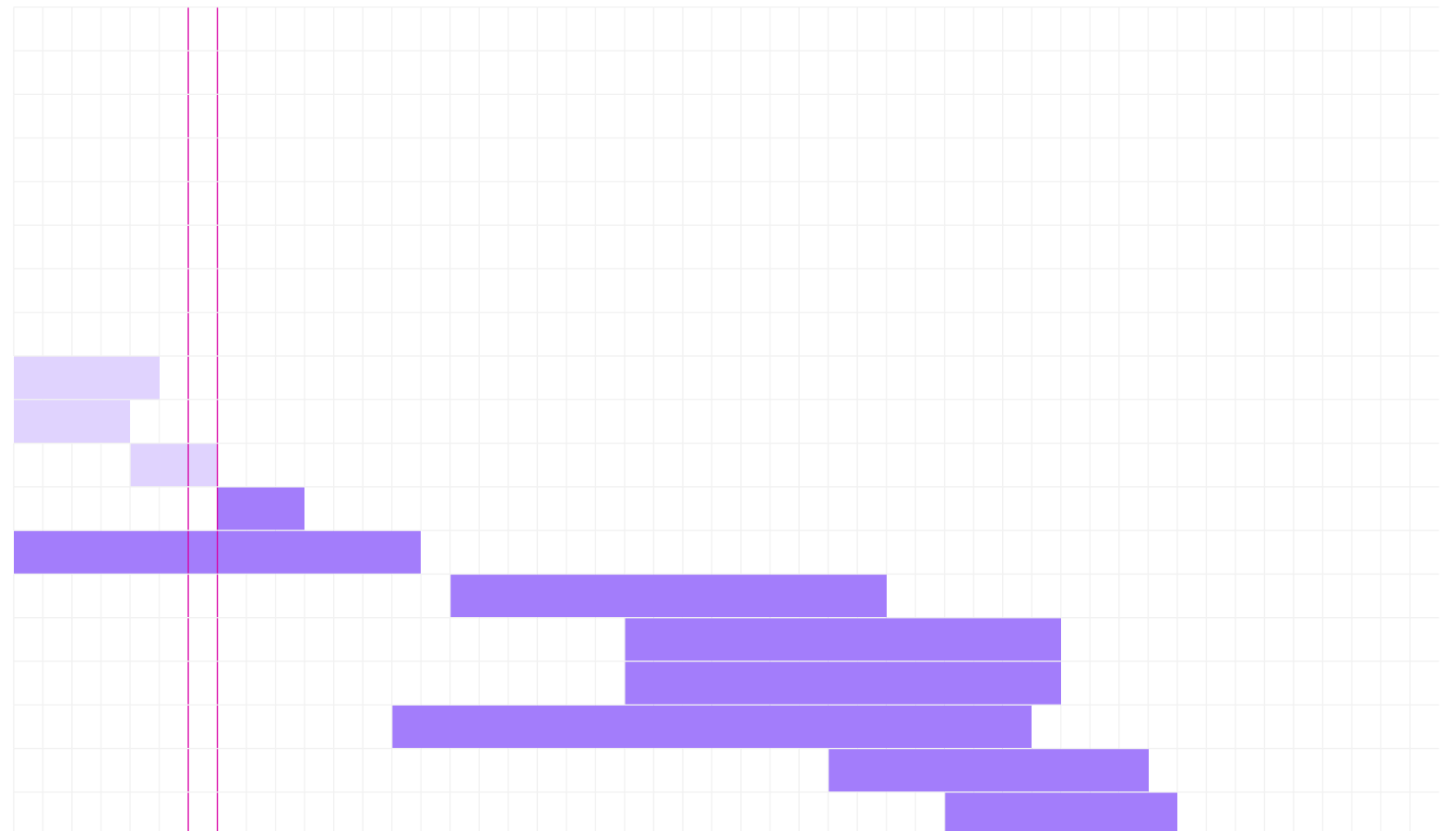
Design Validation

Part # and Functions	Potential Failure Mode	Potential Effect(s) of Failure	Potential Causes and Mechanisms of Failure	RPN	Recommended Action
Motor	water ingress	stop operation, electrical hazard	environmental conditions	40	shield component
Motor	high-cycle fatigue	stop operation	material/component issues, fatigue	42	replace component every 5 years
Roller	fretting wear	misalignment	material/component issues, tolerances	24	replace component every 5 years
Roller	surface fatigue wear	slipping	material/component issues, fatigue	24	replace component every 5 years
Shaft	high-cycle fatigue	fracture	material/component issues, cracking	42	replace component every 5 years
Sensor	water ingress	emergency stop disabled	environmental conditions	40	shield component
Remote Control	connection loss	stop operation	environmental conditions	140	ensure stable connection conditions
Torque Plate	fretting wear	misalignment	material/component issues, tolerances	24	replace component every 5 years
Torque Plate	surface fatigue wear	slipping	material/component issues, fatigue	24	replace component every 5 years
Lead Screw	fretting wear	misalignment	material/component issues, tolerances	24	replace component every 5 years
Lead Screw	high-cycle fatigue	fracture	material/component issues, cracking	42	replace component every 5 years

Schedule

TASK	ASSIGNED TO	PROGRESS	START	END
Course Deliverables				
Presentation 1 Slides	All	100%	9/9/24	9/13/24
Presentation 1 Practice	All	100%	9/13/24	9/15/24
Presentation 1 Revisions	All	100%	9/16/24	9/18/24
Presentation 2 Slides	All	100%	9/26/24	10/3/24
Presentation 2 Practice	All	100%	10/4/24	10/6/24
Presentation 2 Revisions	All	100%	10/7/24	10/9/24
Report 1	All	100%	10/4/24	10/20/24
Website Development 1	All	100%	10/17/24	10/24/24
Analytical Analysis Memo	All	100%	10/18/24	11/1/24
Presentation 3 Slides	All	100%	10/24/24	10/31/24
Presentation 3 Practice	All	100%	11/1/24	11/3/24
Presentation 3 Revisions	All	0%	11/4/24	11/6/24
Prototype 1 Demo	All	20%	10/19/24	11/10/24
Report 2	All	0%	11/12/24	11/26/24
Final CAD	All	0%	11/18/24	12/2/24
Final BOM	All	0%	11/18/24	12/2/24
Prototype 2 Demo	All	0%	11/10/24	12/1/24
Project Management	All	0%	11/25/24	12/5/24
Website Development 2	All	0%	11/29/24	12/6/24

Oct 28, 2024			Nov 4, 2024			Nov 11, 2024			Nov 18, 2024			Nov 25, 2024			Dec 2, 2024			Dec 9, 2024																																					
28	29	30	31	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15							
M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S



Budget - Current

Bill of Materials				
Order 1				
Item	Cost	Quantity	Total cost	Link
Driver Roller	\$30.23	1	\$30.23	https://www.mcn
Idle Roller	\$20.73	3	\$62.19	https://www.mcn
Shipping			\$10.06	
Tax			\$8.48	
Total			\$110.96	
Order 2				
Item	Cost	Quantity	Total cost	Link
Nema 17 5:1 geared stepper motor	\$40.15	1	\$40.15	https://www.ama
Shipping			\$0.00	
Tax			\$3.69	
Total			\$43.84	
BOM Total:			\$154.80	

Income			
From Sponser			\$5,000
From Fundraising	\$500	Current:	\$200.00
Total:			\$5,500
Expenses			
Prototype 1			
Order Number	description		cost
Order 1	Idle and driver rollers for translation		\$110.96
Order 2	NEMA 17 stepper with gear ratio 5:1		\$43.84
Total:			\$154.80
Sum Total:			\$154.80
Budget left			\$5,345
Percent used:			2.81%

Budget - Expected

BOM EXPECTED				
Item	Cost	Quantity	Total cost	Link
Arduino Leonardo	\$24.90	1	\$24.90	https://www.ama
Abrasion-Resistant Idler Rollers	\$26.06	1	\$26.06	https://www.mcm
Tight-Tolerance Drive Rollers	\$32.93	1	\$32.93	https://www.mcm
A4988	\$10.99	1	\$10.99	https://www.ama
Nema 11 Stepper	\$24.15	1	\$24.15	https://www.ama
Rotary force transducer	\$201.88	2	\$403.76	https://www.ama
V-type 12 pc 800 mm	\$64.99	1	\$64.99	https://www.ama
Power Supply	\$31.00	1	\$31.00	https://www.ama
Sum:			\$618.78	

References

[1] T. Becker, “Capstone Catheter Roller Fall24 v1,” unpublished.5

[2] Moldeddimensions, “Frictional characteristics,” Molded Dimensions Group, <https://moldedgroup.com/frictional-characteristics/> (accessed Nov. 4, 2024).

Thank you

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Questions?