Team 1

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“Prep-Less” Door Position Switch

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Customer Background

Allegion has built its company around door security. They currently own over 30 companies focused on securing where people “live, work and visit.” Residential and commercial locks, door closer and exit devices, access control and production systems, as well as even entire doors themselves, are designed by Allegion and their sub-companies. Allegion also employs a wide variety of technical specification writers and experts to create codes and standards to adhere their products to in order to ensure their customers have the best possible security for their businesses and homes.

Problem Statement

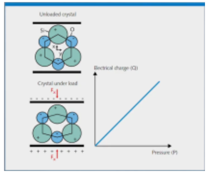
Current DPS (Door Position Switch) technology requires preparation that permanently alters the existing door frame, consumes too much power, and is not reliable for a wide variety of environmental conditions. Allegion’s customers need a robust, “prep-less,” low-power DPS solution that can easily integrate with the rest of Allegion’s products.

Requirements Matrix

Rep. #	Requirement	Description	Test to Verify
1	Low Power	Sensor must be ~< 300 µA, 3.3V, and Battery Friendly.	Use a spec sheet to first verify sensors we order, then test actual product with a voltmeter. If it is within this threshold the test passes. This will be determined by test 0005 Power Draw. Please consult section 3.5 for further details on testing.
2	"DIY" Installation	DPS can be assembled with basic tools in <1 hour; no door prep or technician needed.	When installing the sensor to the door, we can time how long it takes us to set up. We can also document any tools necessary to install the system. If they can be commonly found in households, then the test passes.
3	Detect Open/Closed	NC Switch that can detect opened/closed door states. Door is “open” when there is 0.75” gap between the door frame and the door. With a 36” door that is 1.75” thick, this translates to ~4 degrees.	This is the primary aspect we will be testing in the lab. For both of our sensors, we are trying to measure the angle of the door’s position. We bought a door and frame so we can attach the sensors to the hinge and test this application. This will be a go/no-go style test.
4	Compatibility	Design is Compliant with Standard Door Preparation	Application to all doors. Testing commercial and residential hinges for fitment with implemented sensors. Hinges come in different shapes and sizes, so testing design dimensions and implementation would play a big part in testing.
5	Robust and Accurate	DPS will need to be applicable to industry standard doors or hinges. The solution must be able to measure when a door is open more than 0.75 inches. Exact degrees or distance may be included but not required.	The door will be opened exactly 1/2 inch and a reading will be taken, and then another at exactly 1 inch. The solution will be implemented with an industry standard door in lab.
6	Easily Testable	DPS can be tested with general equipment, like Arduino Microcontroller.	Record readings from our program with each sensor using the Arduino controllers.
7	Wireless or Wire Minimal	Must be battery operated or battery compatible. No external boxes and wires	Visual inspection, just make sure the solution, sensor, battery etc. can all fit within an attachable casing.

Concepts Exploration

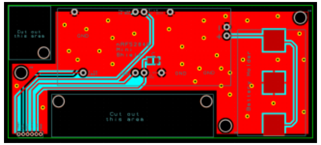
#	Requirement	Weighting Factor	Capacitive Bend Sensor	Photoelectric Sensor	Rotary Sensor	Ultrasonic Sensor
1	Detect Open/Closed	0.21	4	3	4	4
2	"DIY" Installation	0.20	4	1	2	1
3	Low Power	0.20	4	4	3	4
4	Accuracy & Robust Against Environment	0.15	3	3	4	3
5	Wireless or Wire Minimal	0.10	4	1	4	3
6	Easily Testable	0.07	3	2	2	2
7	Compatibility	0.07	2	1	1	2
		Total	24	15	20	19
		Weighted Total	3.64	2.39	3.05	2.87



Capacitive Bend Sensor Physics


Rotary Sensor

Final Design



PCB Design


PCB Assembly


Full Hinge Assembly


nRF52840 Configuration

FMEA

Requirements	Potential Failure Mode	Potential Effect(s) of Failure	Severity	Potential Causes(s) of Failure	Occurrence	Current Design Controls Prevention	Detection	RPN
Sensor shall be able to detect if the door is open or closed	Sensor is not able to power on	No signal is given	8	Battery needs replaced/or is not connected	1	Test Plan to verify the performance of the sensor	2	16
	Sensor does not bend enough to detect a signal	User is not notified of the door opening or closing	8	Sensor is not calibrated accordingly/sensor's precision is not high enough	1	Test Plan to verify the performance of the sensor	2	16
Sensor shall be able detect the exact position of the door	Sensor is not able to power on	No signal is given	8	Battery needs replaced/or is not connected	1	Test Plan to verify the performance of the sensor	2	16
	Sensor does not bend enough to detect a signal	User is not notified of the door opening or closing	8	Sensor is not calibrated accordingly/sensor's precision is not high enough	1	Test Plan to verify the performance of the sensor	2	16
	Sensor is not able to produce a signal which can be de-coded into a position	User doesn't know the exact position of the door	8	Sensor only produces a digital (1/0) signal The software is not reading/interoperating the data correctly	1	Test Plan to verify the performance of the sensor	1	8
Sensor must have a good electrical connections	Sensor cannot be powered on by the battery	The system is unable to detect the position of the door	8	Sensor cannot be powered by the battery Sensor was not wired up correctly	1	Fit Check and Installation Procedures	1	8
	The wrong signal is sent to the user	Wrong position of the door is sent to the user	7	Sensor was not wired up correctly	1	Fit Check and Installation Procedures	3	21
	No signal is able to be produced	The system is unable to detect the position of the door	8	Sensor was not wired up correctly	1	Fit Check and Installation Procedures	2	16
Sensor must be robust against environmental factors	Sensor is not able operate	No signal is given	8	dirt, water, and any other foreign particles impeed the electrical connection of the sensor	1	Test Plan to verify the performance of the sensor	6	48
	Sensor sends inaccurate data	The wrong postion of the door is given to the user	7	dirt, water, and any other foreign particles impeed the electrical connection of the sensor	1	Test Plan to verify the performance of the sensor	6	42
Sensor must be easily testable	User cannot confirm that the system is sending accurate data	Sensors sends inaccurate data	5	Sensor requires additional components and software to operate	1	Test Plan to verify the performance of the sensor	2	10
Sensor must be compatible with current allegion door locks	Positon of the door cannot be sent to user	The sensor is not able to send data to the door locking system	8	Sensor is not compadible with the hardware and/or software inside the door lock	1	Test Plan to verify the performance of the sensor	2	16
Sensor must fit inside frame/hinge of the door	The door is unable to close properly	Additional prep must be done to the hinge or door/frame	5	Sensor and/or its wiring too big to fit within a hinge	1	Fit Check and Installation Procedures	3	15
Wiring must be low profile and reach Allegion door lock	wire length is not long enough	An electrical connection cannot be made with the Allegion door lock	6	Proper stripping and/or twisting of the wire does not meet required measurement	1	Fit Check and Installation Procedures	2	12
Sensor shall be placed securely inside the hinge	Sensor becomes detached from the hinge	Sensor is not able to send accurate data	4	Sensor was not attached to the hinge properly	1	Fit Check and Installation Procedures	2	8
Sensor shall have a 365,000 cycle life (10-year life, 100 cycles per day)	Rubber becomes worn over time	In accurate data being read from the sensor Failure of the Sensor	8	Capaciter Plates crack due sensor not capable of such lifespan	2	Test Plan to verify the performance of the sensor	3	48
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	The sensors board is damaged by the door	Failure of the sensor	8	The sensor is not able to be placed inside the hinge	1	Test Plan to verify the performance of the sensor Fit Check and Installation Procedures	2	16
	Rotation knob of sensor breaks	Failure of the sensor	8	Stress of knob inside hinge over time	2	Test Plan to verify the performance of the sensor Fit Check and Installation Procedures	4	64
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Testing

Test ID	Req. Matrix	Test Name	Specifications & Test Methods	Test Description	Test Results
0001	5 - Robust and Accurate	Perpendicular Pressure Test	Test effects of pressure applied to the side of the bend sensor	Pass - Pressure does not cause a signal change greater then 1 degree from the sensor Not Pass - Pressure causes a signal change greater than 1 degree in the sensor	Pressures exceeding 10psi cause the sensor output to change more than 1 degree. Sensor output returns to original value after pressure is removed
0002	5 - Robust and Accurate	Resolution Test	Determine the minimum achievable resolution to verify the theoretical resolution from the datasheet	The smallest detectable change in angular position.	Pass
0003	5 - Robust and Accurate	Stretch Test	Test effects of axial tensile loads on the bend sensor	Pass - Load does not induce signal change greater than 1 degree Not Pass - Load induces signal change greater than or equal to 1 degree	Stretching the sensor causes extreme and unpredictable changes in the output. The sensor required recalibration after being stretched.
0004	-	Localized vs Distributed Strain Test	Verify the concept of path impedence (ensuring there is no difference between localized and distributed bend strains)	No test requirement, this concept is not design critical but nice to know information for further development	Sensor functions as outlined in theory guide from manufacturer
0005	1 - Low Power	Power Draw	Determine power requirements for the bend sensor and validate published values	Pass - Current draw < 300uA Not Pass - Current draw >= 300uA	Pass
0006	1 - Low Power	Power vs Sample Rate	Determine the effects of sample rate of the power consumption of the bend sensor.	The sample rate that produces a 300uA average current draw	Pass
0009	5 - Robust and Accurate	Creep Test	Ensure the sensor output will not gradually drift after prolonged periods of time.	The bend sensor output should not drift more than 1 degree	Pass
0007	5 - Robust and Accurate	Vibration Test	Ensure the sensor output is unaffected to external vibrations	The bend sensor output should not change by more than 1 degree	Pass
0010	-	Vibration Sensor Test	Determine viability of vibration sensor to wake-up DPS during motion while from a door hinge.	Pass-Produces Signal when test surface is moved uniformly or when vibrated/nudged Not Pass-Does not produce signal during either or both of the tests	The sensor sent signals when nudged and vibrated, but no amount of motion from the test produced a signal.