



A Johnson Electric Company

# Qualification Test Report

## RS-08 Rotary Shutter

Document No. S600421000-00 rev D



This document is valid as of the date of the latest ECO listed below. Before beginning work check in PRIORITY to ensure that you have the latest revision.

### AUTHORIZATION

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### REVISION HISTORY

ECO	Rev.	Description of Revisions	Changed by:	Date/Sign
--	A	Initial release	Leonardo B.	July-2013
--	B	Revised formatting	Melvin L	
--	C	Added copies of Ram Craft Ltd test reports and incorporated review comments		
	D	Add Gunfire test	Einat S	June-2016

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# 1 INTRODUCTION

## 1.1 PURPOSE

RS-08 units were subjected to qualification tests as part of standard Nanomotion Ltd Product Qualification process.

## 1.2 OVERVIEW

The RS-08 Rotary Shutter is an electro-mechanical assembly which serves bolometric infrared detectors for Non Uniformity Correction (NUC). The Rotary Shutter consists of a high emissivity blade and a piezoelectric actuator, which moves the blade right and left. The blade blocks detector field of view in order to perform NUC operation. Applicable Documents

- Rotary Shutter Specifications
- Acceptance Test Procedure - Rotary Shutter

The following table provides an overview of the qualification tests and results.

**Table 1: Summary of Qualification Test Results**

Test	Description	Results
Acceptance Test Procedure	Standard performance tests for Rotary Shutter	Tested units performance is within ATP limits
Thermal stress (Storage)	comparison of performance before and after exposure to temperatures between -40 and +70 C	Tested units performance is within ATP limits
Temperature Performance	Unit performance vs. temperature between -40 and +70 C	Acceptable performance within the specified operating temperature range

**Table 1: Summary of Qualification Test Results**

Test	Description	Results
Vibration Tests	Units tested under white noise random vibrations of bandwidth between 5Hz and 2000 Hz of sequentially increasing acceleration levels: 3, 5, 7 and 10gRMS, and sequentially applied along 3 perpendicular directions: x, y, z.  Comparison of units performance before an after exposure to vibrations	Tested units maintained functionality during the vibrations.  Tested units performance is within the limits after exposure to vibrations
Shock Tests	Teste units endured shocks up 6to 500 g/0.8 ms half sine,  Unit of 35 stroke endured further stronger shocks of up to 750 g/0.8 ms half sine	The units remained operational holding position or correcting position (X axis) with 70 msec during shocks. Tested units performance is within ATP limits after enduring the shocks protocol
Gunfire Test	Two units (90° travel) were mounted on an M4 rifle while firing 1,500 rounds. One unit mounted at Y direction and one on Z direction.	Tested units performance is within ATP limits
Lifetime Test	endurance of performance after continuous operation (up to about 1 million cycles	Tested units performance is within ATP limits

## 2 QUALIFICATION TESTS

### 2.1 TESTS DEFINITIONS

The test program includes the following activities:

- Unit Acceptance Test Procedure (ATP)
- Temperature performance
- Vibrations test
- Shock test
- Gunfire test
- Lifetime test
- Reliability test

## **2.2 UNIT ACCEPTANCE TEST PROCEDURE (ATP)**

### **2.2.1 TEST DESCRIPTION**

Standard tests:

- Current Consumption
- Drive Frequency Calibration
- OPEN-CLOSE Time
- Static & Dynamic Force

Standard tests are conducted after exposure to temperature cycles between -40°C to 70°C according to the following temperature profile depicted in [Thermal Stress Profile on page 7](#)

### **2.2.2 TEST EQUIPMENT**

In order to carry out the tests program the following equipment was used:

- Temperature chamber type: Thermotron S-1.2-2800
- Rotary Shutter ATP setup

### **2.2.3 TEST RESULTS**

Refer to [Acceptance Test Procedure on page 7](#).

### **2.2.4 TEST SUMMARY**

Tested units' performance is within ATP limits

## **2.3 TEMPERATURE PERFORMANCE**

### **2.3.1 TEST DESCRIPTION**

Dynamic performance while operation in the temperature range of -40°C to +70°C

### **2.3.2 TEST EQUIPMENT**

In order to carry out the tests program the following equipment was used:

- Temperature chamber type: Thermotron S-1.2-2800
- Rotary Shutter units on a support plate inside a thermal chamber

### **2.3.3 TEST RESULTS**

Refer to [Temperature Performance \(45° Stroke\) on page 10](#).

### **2.3.4 TEST SUMMARY**

Performance within the specifications for operating temperature range

## **2.4 VIBRATION TESTS**

Test Description

- Two Rotary Shutter units (one of 35° travel and one of 120° travel) were tested under white noise random vibrations of bandwidth between 5Hz and 2000 Hz of sequentially increasing acceleration levels: 3, 5, 7 and 10 g RMS, and sequentially applied along 3 perpendicular directions: z, x and y
- Each vibration level was applied during 10 minutes
- Units performance was monitored during vibrations exposure by means of data collection and logging to a computer file
- Data collection was done at 500 Hz
- ATP after exposure to vibrations at each vibration level

### **2.4.1 TEST EQUIPMENT**

Refer to [Vibration Test Setup on page 12](#).

### **2.4.2 TEST RESULTS**

Refer to [Vibration Tests on page 12](#).

### **2.4.3 TEST SUMMARY**

The units performed to specification before and after exposure.

- The shutters withstood the vibration
- The shutters were able to hold position during vibrations
- Motion under vibration is repeatable and within the travel time specifications

## **2.5 SHOCK TEST**

### **2.5.1 TEST DESCRIPTION**

- Two Rotary Shutter units (one of 35° travel and one of 120° travel) were exposed sequentially to a series of 10 half sine shocks with a duration of 0.8 ms and a peak acceleration of 300g, 400g and 500g and sequentially applied along 3 perpendicular directions: z, x and y
- Unit 35° was tested and endured further stronger shocks of up to 750g/0.8 ms half sine
- Performance tests after enduring each shock series

### **2.5.2 TEST EQUIPMENT**

Refer to [Shock Test setup on page 19](#).

### **2.5.3 TEST RESULTS**

Refer to [Shock Tests on page 19](#).

### **2.5.4 TEST SUMMARY**

The units remained operational holding position or correcting position (X axis) within 70ms during shocks.

Tested units' performance is within ATP limits after enduring the shocks protocol

## **2.6 GUNFIRE TEST**

### **2.6.1 TEST DESCRIPTION**

- Three Rotary Shutter units (90° travel) were mounted on an M4 rifle while firing 1,500 rounds. Two unit mounted at Y direction and one on Z direction.
- Performance tests will be tested after 300, 700, 1,000 and 1,500 rounds

### **2.6.2 TEST EQUIPMENT**

Refer to [Gunfire Test setup on page 21](#).

### **2.6.3 TEST RESULTS**

Refer to [Shock Tests on page 22](#).

### **2.6.4 TEST SUMMARY**

Tested units' performance is within ATP limits after firing 1,500 rounds



## 2.7 LIFETIME TESTS

### 2.7.1 TEST DESCRIPTION

Endurance of performance after continuous operation (exceeding 1 million cycles)

### 2.7.2 TEST EQUIPMENT

ATP setup

### 2.7.3 TEST RESULTS

Refer to [Lifetime Tests on page 23](#).

### 2.7.4 TEST SUMMARY

Functional units after test. Performance within specifications allowing up to 30% degradation in transient time.

## 2.8 RELIABILITY PREDICTION

The following are the results of the reliability prediction for the MRS at 35° C Ambient temperature and GM Environmental condition.

$$= 18.30 \times 10^{-6}$$

MTBF = 54,658 hours

### 2.8.1 DETAILED COMPONENTS MTBF

Table 1 presents the detailed modules/cards reliability data.

**Table 2: MRS modules/cards Reliability Dat**

ID	Part name	QTY	FR x10-6	MTBF [hrs]
1.1	Shutter Assembly	1	12.38	80,791
1.2	Edge Motor Driver	1	5.92	168,979

## APPENDIX 1 ACCEPTANCE TEST PROCEDURE

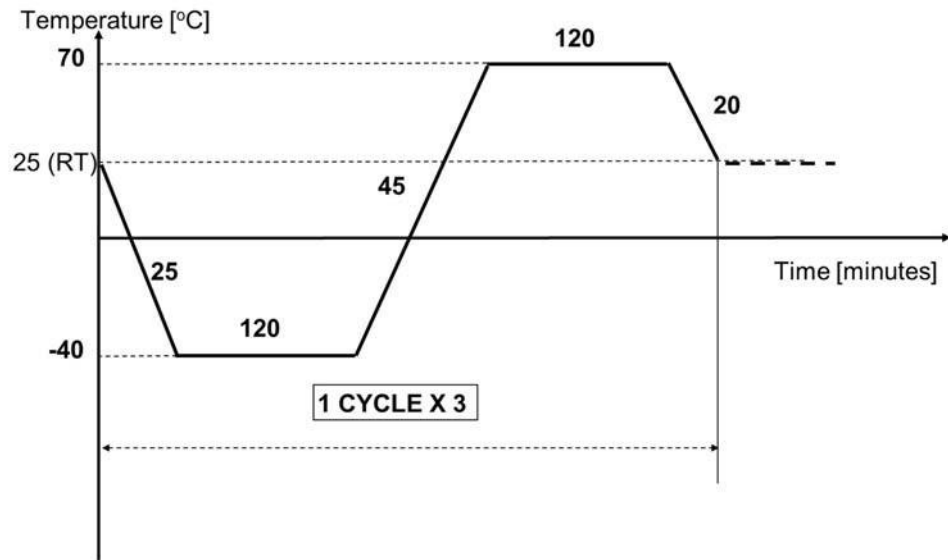


Figure 1: Thermal Stress Profile

Controller/Driver SW version:

EDGE1R\_01-01-00-05

Communications check:

- Adapter ver 1.0.0.6
- Controller ver 1.1.0.5
- Application 2.9

**Table 3: ATP Results**

Test	Details	RS-08 Serial Number					AVG
		20130021	20130026	20130024	20130029	20130030	
Voltage Test	Supply Voltage [V] 3.3V ±5%	OK	OK	OK	OK	OK	OK
Current test	Current consumption [ma] <100 mA	55	84	64	64	80	69.4
Calibration	run protocol 3 times and check same frequency for at least 2 times [khz]	160	151.5	153.8	157.5	151.5	154.9
Time readings OPEN	Command OPEN/CLOSE & check parameter 12, time [ms] less than 150 [ms] for each direction	95	113	136	111	101	111.2
Time readings CLOSE	Command OPEN/CLOSE & check parameter 12, time [ms] less than 150 [ms] for each direction	108	103	123	123	103	112
run script shutter.txt	Check leaf movement and reach end of travel without errors	OK	OK	OK	OK	OK	OK
Dynamic Force OPEN	Measure dynamic stall force [N] by means of force gauge applied at the end of the square leaf > 0.03N	0.06	0.048	0.052	0.044	0.052	0.051
Dynamic Force CLOSE	Measure dynamic stall force [N] by means of force gauge applied at the end of the square leaf >0.03N	0.04	0.064	0.054	0.054	0.066	0.056
Static Force OPEN	Measure static force [N] by means of force gauge applied at the end of the square leaf >0.03N*	0.05	0.046	0.034	0.032	0.036	0.04
Static Force CLOSE	Measure static force [N] by means of force gauge applied at the end of the square leaf >0.03N*	0.042	0.066	0.044	0.045	0.044	0.048

\* The Force was measure from the rotating axis to the end of the blade (27.7 mm)

## APPENDIX 2 TEMPERATURE PERFORMANCE (45° STROKE)

Maximum PWM = 30000

**Table 4: Temperature Performance (45° Stroke)**

Temp. °C	Parameter	RS-08 Serial Number									
		20130015	20130017	20130020	20120016	20130011	20130012	20130013	20130018	20130014	20130019
24	FREQ [kHz]	155	153.8	151.5	151.5	160	157.5	153.8	155	151.5	151.5
	PWM Min	5500	5000	4500	5000	5000	5000	7000	5500	5500	6000
	Open Duration [ms]	45	50	41	45	45	42	47	44	45	41
	Close Duration [ms]	45	52	47	46	46	51	55	49	46	50
-40	FREQ [kHz]	160	157.5	155	155	163.9	161.3	157.5	158.7	155.0	157.5
	PWM Min	8000	7000	8500	11000	12000	11000	12500	7500	9000	9500
	CALIB FREQ [kHz]	160	155	151.5	151.5	153.8	153.8	153.8	160	153.8	153.8
	PWM Min After Calibration	7000	7500	8000	9000	9000	11000	9000	7500	9500	9500
	Open Duration [ms]	55	66	85	90	74	100	64	61	100	72
	Close Duration [ms]	58	69	90	90	63	75	83	61	60	65

**Table 4: Temperature Performance (45° Stroke)**

Temp. °C	Parameter	RS-08 Serial Number									
		20130015	20130017	20130020	20120016	20130011	20130012	20130013	20130018	20130014	20130019
70	FREQ [kHz]	155	149.3	146.0	149.3	148.1	155.0	148.1	153.8	148.1	148.1
	PWM MIN	6000	6000	5000	5500	5500	5000	7000	5500	5000	5000
	CALIB FREQ [kHz]	155	153.8	155	155	155	153.8	160	155	151.5	5000
	PWM Min After Calibration	6000	6000	5000	6000	6000	5000	7000	6500	6000	4500
	Open Duration [ms]	44	48	47	42	53	43	48	51	51	44
	Close Duration [ms]	47	50	40	50	43	45	51	50	44	45

### APPENDIX 3 VIBRATION TESTS



Figure 2: Vibration Test Setup

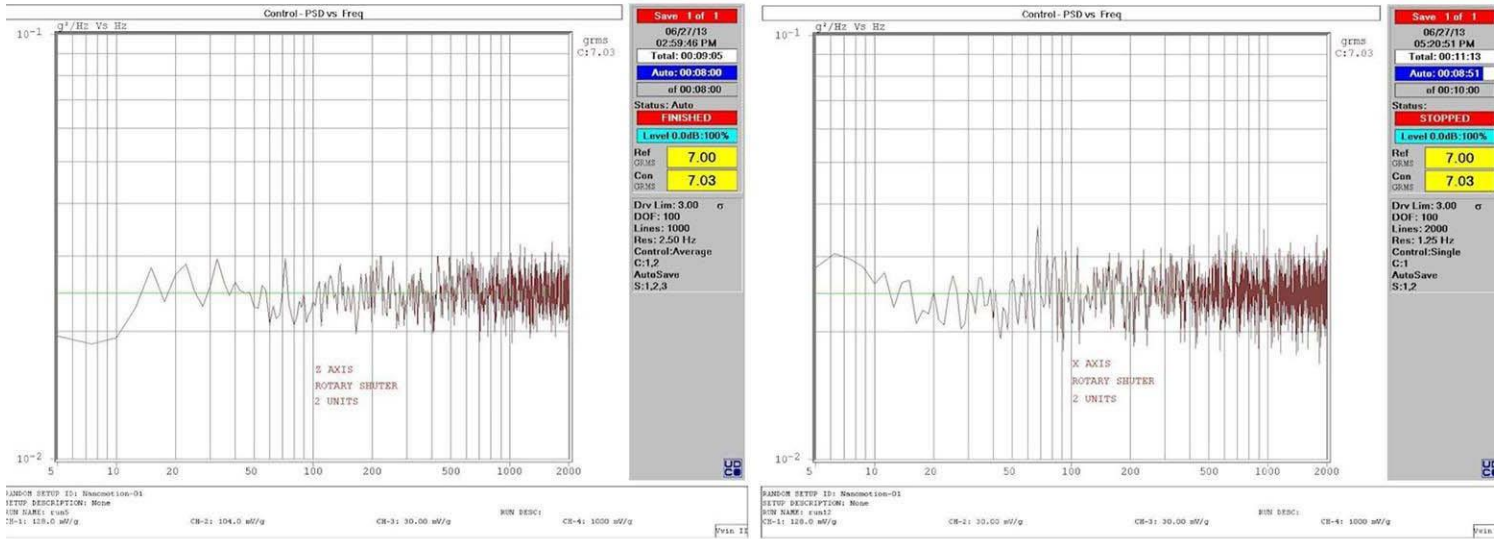


Figure 3: Examples of Random Vibrations Profiles

Controller/Driver SW version: EDGE1R\_01-01-00-05

Communications check:

- Adapter ver 1.0.0. 6
- Controller ver 1.1.0.5
- Application 2.9

Table 5: Test Results During Vibration Test (35° stroke)

Test	Details	35 degrees (Before Vibrations)	Tests After Vibration Level										
			Z 3 g RMS	Z 5 g RMS	Z 7 g RMS	Z 10 g RMS	X 3 g RMS	X 5 g RMS	X 7 g RMS	X 10 g RMS	Y 5 g RMS	Y 7 g RMS	Y 10 g RMS end of vibrations
Voltage Test	Supply Voltage [V] 3.3V ±5%	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Voltage Test	Supply Voltage [V] 3.3 V ±5%	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Current test	Current consumption [ma] < 100 mA	100	72	84	84	86	80	80	72	78	83	86	90
Calibration	run protocol 3 times and check same frequency [kHz] for at least 2 times	151.5	153.8	151.5	155	151.5	155	151.5	151.5	155	151.5	151.5	151.5
Time readings OPEN	Command OPEN/ CLOSE & check parameter 12, time [ms] less than 80 ms for each direction	66	68	69	69	69	69	69	69	69	70	72	69
Time readings CLOSE	Command OPEN/ CLOSE & check parameter 12, time [ms] less than 80 ms for each direction	72	74	75	74	75	75	74	74	75	75	78	73



Table 5: Test Results During Vibration Test (35° stroke)

Test	Details	35 degrees (Before Vibrations)	Tests After Vibration Level										
			Z 3 g RMS	Z 5 g RMS	Z 7 g RMS	Z 10 g RMS	X 3 g RMS	X 5 g RMS	X 7 g RMS	X 10 g RMS	Y 5 g RMS	Y 7 g RMS	Y 10 g RMS end of vibrations
run script shutter.txt	Check leaf movement and reach end of travel without errors	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Dynamic Force OPEN	Measure dynamic stall force [N] by means of force gauge applied at the middle of the square leaf	0.092	0.056	0.058	0.058	0.052	0.048	0.06	0.04	0.062	0.058	0.066	0.048
Dynamic Force CLOSE	Measure dynamic stall force [N] by means of force gauge applied at the middle of the square leaf*	0.06	0.062	0.064	0.056	0.06	0.062	0.064	0.04	0.058	0.04	0.056	0.058
Static Force OPEN	Measure static force [N] by means of force gauge applied at the middle of the square leaf*	0.05	0.08	0.046	0.046	0.06	0.058	0.062	0.068	0.07	0.06	0.04	0.054

**Table 5: Test Results During Vibration Test (35° stroke)**

Test	Details	35 degrees (Before Vibrations)	Tests After Vibration Level										
			Z 3 g RMS	Z 5 g RMS	Z 7 g RMS	Z 10 g RMS	X 3 g RMS	X 5 g RMS	X 7 g RMS	X 10 g RMS	Y 5 g RMS	Y 7 g RMS	Y 10 g RMS end of vibrations
Static Force CLOSE	Measure static force [N] by means of force gauge applied at the middle of the square leaf*	0.05	0.068	0.052	0.07	0.05	0.066	0.066	0.07	0.04	0.04	0.062	0.054

\* The Force was measure from the rotating axis to the end of the blade (27.7 mm)

## Test Results During Vibration Test (120° stroke)

Controller/Driver SW version: EDGE1R\_01-01-00-05

Communications check:

- Adapter ver 1.0.0.6
- Controller ver 1.1.0.5
- Application 2.9

**Table 6: Test Results During Vibration Test (120° stroke)**

Test	Details	120 degrees (BEFORE VIBRATIONS)	Tests After Vibration Level					
			Z 3 g RMS	Z 5 g RMS	Z 7 g RMS	Z 10 g RMS	X 3 g RMS	X 5 g RMS
Voltage Test	Supply Voltage [V]: 3.3V ±5%	OK	OK	OK	OK	OK	OK	OK
Voltage Test	Supply Voltage [V]: 3.3 V ±5%	OK	OK	OK	OK	OK	OK	OK
Current test	Current consumption [ma] < 100 mA	100	88	100	92	86	90	88
Calibration	run protocol 3 times and check same frequency for at least 2 times	161.3	161.3	157.5	161.3	161.3	161.3	161.3
Time readings OPEN	Command OPEN/CLOSE & check parameter 12, time [ms] less than 150 ms for each direction	110	127	126	128	128	126	128
Time readings CLOSE	Command OPEN/CLOSE & check parameter 12, time [ms] less than 150 ms for each direction	100	121	118	121	121	121	120

**Table 6: Test Results During Vibration Test (120° stroke)**

Test	Details	120 degrees (BEFORE VIBRATIONS)	Tests After Vibration Level					
			Z 3 g RMS	Z 5 g RMS	Z 7 g RMS	Z 10 g RMS	X 3 g RMS	X 5 g RMS
run script shutter.txt	Check leaf movement and reach end of travel without errors	OK	OK	OK	OK	OK	OK	OK
Dynamic Force OPEN	Measure dynamic stall force [N] by means of force gauge applied at the middle of the square leaf	0.05	0.036	0.04	0.06	0.046	0.06	0.048
Dynamic Force CLOSE	Measure dynamic stall force by means of force gauge applied at the middle of the square leaf	0.065	0.054	0.08	0.052	0.062	0.046	0.068
Static Force OPEN	Measure static force [N] by means of force gauge applied at the middle of the square leaf	0.036	0.082	0.06	0.06	0.058	0.048	0.05
Static Force CLOSE	Measure static force [N] by means of force gauge applied at the middle of the square leaf	0.037	0.062	0.054	0.058	0.07	0.06	0.06

## APPENDIX 4 SHOCK TESTS



Figure 4: Shock Test setup

Controller/Driver SW version: EDGE1R\_01-01-00-05

Communications check

- Adapter ver 1.0.0. 6
- Controller ver 1.1.0.5
- Application 2.9

**Table 7: Shock Test Results**

Test	Details	Go mark No Go mark	35 degrees (Before Shocks)	Tests After Vibration Level											35 degrees (After Shocks)	
				X1 300g	X2 400g	X3 500g	Y1 300g	Y2 400g	Y3 500g	Z1 300g	Z2 400g	Z3 500g	Z4 600g	Z5 700g- 750g		
Voltage Test	Supply Voltage [V] 3.3V $\pm$ 5%	OK	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30
Current test	Current consumption [ma] <100 mA	OK	73	80	80	100	100	100	80	100	100	100	100	100	100	90
Calibration	run protocol 3 times and check same frequency [kHz] for at least 2 times	OK	151.5	151.5	151.5	151.5	151.5	151.5	151.5	151.5	151.5	151.5	151.5	151.5	151.5	151.5

**Table 7: Shock Test Results**

Test	Details	Go mark No Go mark	35 degrees (Before Shocks)	Tests After Vibration Level											35 degrees (After Shocks)
				X1 300g	X2 400g	X3 500g	Y1 300g	Y2 400g	Y3 500g	Z1 300g	Z2 400g	Z3 500g	Z4 600g	Z5 700g- 750g	
Time readings OPEN	Command OPEN/CLOSE & check parameter 12, time [ms] less than 80 ms for each direction	OK	69	67	67	67	66	71	76	71	71	68	67	72	80
Time readings CLOSE	Command OPEN/CLOSE & check parameter 12, time [ms] less than 80 ms for each direction	OK	67	69	64	65	64	74	69	75	75	63	62	66	70

## APPENDIX 5 GUNFIRE TEST





**Table 9: Gunfire Test Results**

Test	Details	SN 23160009				SN 23160003				23160008						
		Before	ATP Results After XXX round				Before	ATP Results After XXX round				Before	ATP Results After XXX round			
			300	700	1000	1500		300	700	1000	1500		300	700	1000	1500
Voltage Test	Supply voltage [V] 3.3V ±5%	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	ok	OK	OK	OK	OK
Time readings OPEN	Command OPEN/CLOSE & check parameter 12, time [ms] less than 130 ms for each direction with travel of 90°	69.5	78	65	70	76	64	65	65	68	71	94	70	81	70	60
Time readings CLOSE	Command OPEN/CLOSE & check parameter 12, time [ms] less than 130 ms for each direction with travel of 90°	70.1	76	88	73	67	70	75	89	99	92	120	104	80	110	100
run script shutter.txt	Check leaf movement and reach end of travel without errors	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK

## APPENDIX 6 LIFETIME TESTS

Controller/Driver SW version: EDGE1R\_01-01-00-05

Communications check:

- Adapter ver 1.0.0. 6
- Controller ver 1.1.0.5
- Application 2.9

**Table 8: Life Time Test Results**

<b>Test</b>	<b>Details</b>	<b>ATP Results Before Life Test Cycles</b>	<b>ATP Results After 1M cycles</b>
Voltage Test	Supply voltage [V] 3.3V $\pm$ 5%	OK	OK
Current test	Current consumption 200-250mA 100% PWM	240	240
Calibration	run protocol 3 times and check same frequency [kHz] for at least 2 times	157.5	151
Time readings OPEN	Command OPEN/CLOSE & check parameter 12, time [ms] less than 150 ms for each direction with travel of 120°	50	78
Time readings CLOSE	Command OPEN/CLOSE & check parameter 12, time [ms] less than 150 ms for each direction with travel of 120°	50	85
run script shutter.txt	Check leaf movement and reach end of travel without errors	OK	OK

## APPENDIX 7 RELIABILITY PREDICTION

This following is a copy of the Reliability Prediction, document number RC59-360-0337, supplied by Ram Craft Ltd.

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## **APPENDIX 8 FAILURE MODE EFFECTS ANALYSIS (FMEA)**

This is a copy of the Reliability Prediction, document number RC59-360-0338, supplied by Ram Craft Ltd.

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