EMI Test Lab LLC
Electro Magnetic Interference Testing
EmiTestLab.com

FCC Part 15 Subpart B Class A

Verification Test Report

Industry Canada ICES-003 Test Report

Regarding Emissions Compliance of the

LulzBot TAZ 5 3D Printer

For Aleph Objects, Inc.

In Accordance with the Emissions Standards

FCC's Title 47 CFR Part 15 Subpart B Class A

ICES-003 Information Technology Equipment Class A

Revision History

Release	Date	Description
1.0	23 February 2015	Initial release

Description of Equipment Under Test (EUT)

Test Item	:	LulzBot TAZ 5 – 3D Printer
Manufacturer	:	Aleph Objects, Inc.
Receipt date	:	28 January 2015

Manufacturer's information

Manufacturers Representative	:	Chris Wagner
Company	:	Aleph Objects, Inc.
Address	:	626 West 66th Street Loveland, Colorado 80538 U.S.A.
Website	:	https://www.alephobjects.com/index.html

Tests Performed at

Address	:	EMI Test Lab LLC 1822 Skyway Drive Unit J Longmont, Colorado 80504 U.S.A
Website	:	http://www.emitestlab.com/

Test Specifications	:	FCC Part 15 Subpart B Class A, ICES-003 Class A
Tests completed	:	4 Feb 2015
Result of Testing	:	**The EUT is in Compliance with FCC Part 15 Class A for commercial use and ICES-003 for commercial use (Canada)**
Senior EMC Engineer	:	Dennis King
Report written by	:	Dennis King – EMI Test Lab
Test Plan	:	Dennis King for Aleph Objects
Report date	:	23 February 2o15

These test results relate only to the specific unit that was tested. A periodic production audit to verify continued compliance is recommended.

Table of Contents

1 General

1.1 Applied Standards

The LulzBot TAZ 5 3D Printer, made by Aleph Objects, Inc., was evaluated for emissions using the FCC's Title 47 CFR Part 15 Subpart B Class A for commercial use and Industry Canada's ICES-003 Issue 5 Class A.

The following documents were also used as guidance for testing;

- (a) Canadian Standards Association Standard CAN/CSA-CISPR 22-10, *Information technology equipment — Radio disturbance characteristics — Limits and methods of measurement*

    - This is an adoption with Canadian deviations of the identically titled IEC (International Electrotechnical Commission) Standard CISPR (International Special Committee on Radio Interference) 22, Sixth edition, 2008-09.

- (b) ANSI C63.4, *American National Standard for Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz*, 2009

1.2 Detailed description of the test configuration, input and output ports

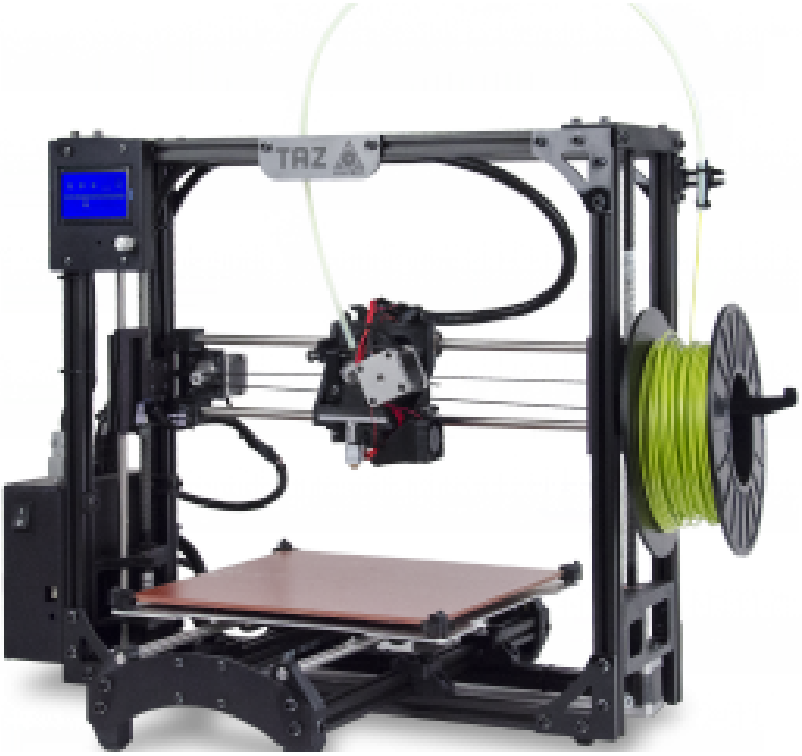
The 3D Printer was tested while printing a 3D “Rocktopuss”. The printer was connected to a laptop through the usb port on the printer. The software was installed on the laptop by Aleph Objects and represents typical software currently used by the end user.

For all test configurations the equipment under test (EUT) is powered by North American AC power: 120VAC/60Hz. All I/O cables are less than 3 meters.

LulzBot TAZ 5 Software:

The default software for the LulzBot TAZ 5 3D printer is called Cura LulzBot Edition. Cura is a Free Software program that both prepares your files for printing (by converting your model into GCODE), and also allows you to control the operation of your LulzBot 3D printer. The revision used during the testing was 14.09.

Firmware loaded on the TAZ 5 was Marlin 2014Q4



https://www.lulzbot.com/products/lulzbot-taz-5-3d-printer

1.2.1 Description of test configuration

EUT	:	LulzBot TAZ 5 3D Printer
Manufacturer	:	Aleph Objects, Inc.
System model name	:	TAZ 5
Serial Number	:	KT-PR0016-8075
Test Voltage	:	120 VAC 60 Hz

1.2.2. Description of tested input and output ports and power supply information

Number of cable type	Type of Cable	From	To	Shielded?	Remarks - length
1	USB	Test Laptop	LulzBot TAZ5	Yes	Typical 6 ft. usb cable, no ferrites

Power supply location	Manufacturer	Model	Serial number	Shielded	Remarks
External AC supply	N/A	PC-240167	PC-1412200510	Plastic enclosure	CE and FCC marks – Output; 24V 16.7A

1.2.2 Operation modes

During preliminary testing for emissions it was determined that the following configurations are worst case for emissions. All further testing was done in this mode.

The system is operating in a typical mode as used by the end user.

The 3D Printer was tested while printing a 3D “Rocktopuss”. The printer was connected to a laptop through the usb port on the printer. The software was installed on the laptop by Aleph Objects and represents typical software currently used by the end user.

All testing was done a 120 VAC 60 Hz, the nominal North American voltage and frequency.

2 Emissions

The EUT (equipment under test) has been tested to determine conformity with the relevant emissions parts of the FCC's Title 47 CFR Part 15 Subpart B Class A for commercial use - section 15.107 for conducted and section 15.109 for radiated - and ICES-003 Issue 5 Class A for Canada.

AC Power line conducted and radiated field strength measurements concerning the emission of radiated and conducted electromagnetic disturbances were made.

2.1 AC Mains Power Input Ports

The disturbance voltage emissions levels at the AC mains power port of the EUT were measured in conformity with and according to the criteria as stated below.

Basic standard	:	FCC Part 15, Subpart B, ICES-003 Issue 5
Test method	:	ANSI C63.4, CAN/CSA – CISPR 22-10
Frequency range 1	:	0.15 – 0.5 MHz
Limit	:	79.0 dBuV quasi peak, 66 dBuV average
Frequency range 2	:	0.5 – 30 MHz
Limit	:	73 dBuV quasi peak, 60 dBuV average

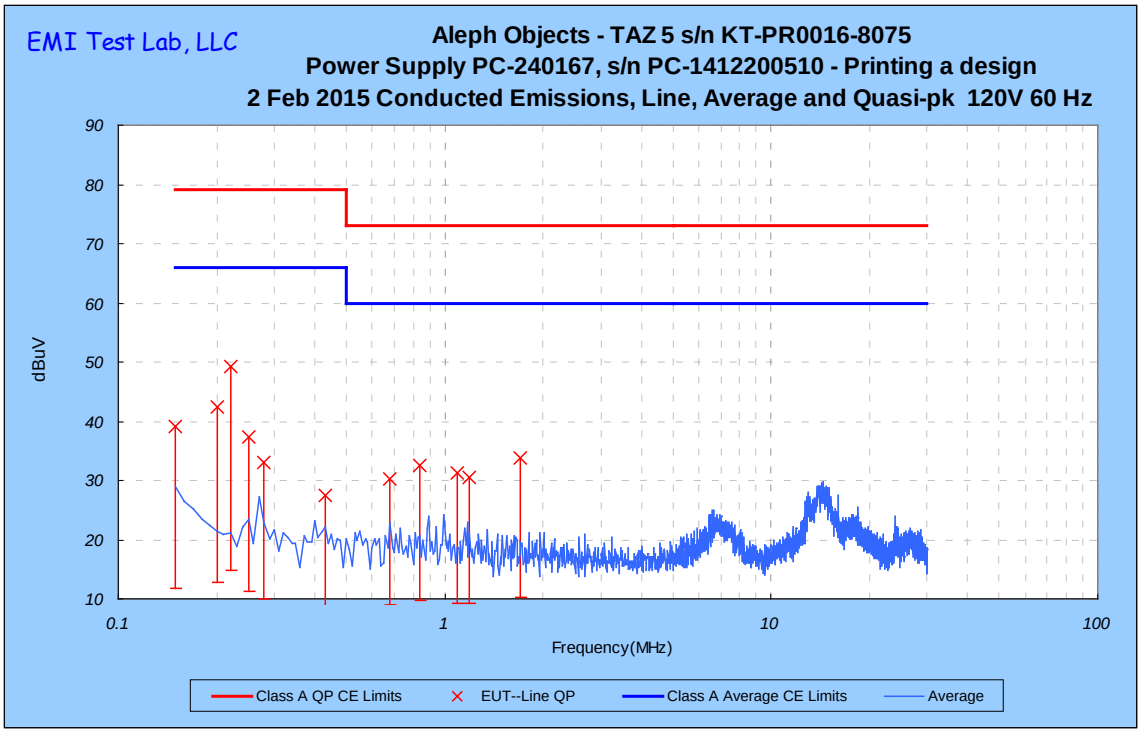
Results of the measurements concerning the emissions of voltage levels at the AC mains input port of the EUT.	**PASS Class A**
Name of Test Engineer: Signature: Date:	Dennis King  2 February 2015

Remarks. The configuration was tested at 120VAC 60Hz.

Conducted Emission Summary:

Peak data was over the Quasi Peak limit but when measured Quasi Peak, those frequencies are passing. All Average scans passed Average limits.

The unit was printing during all conducted emissions tests. PASS



120 VAC 60 Hz Line

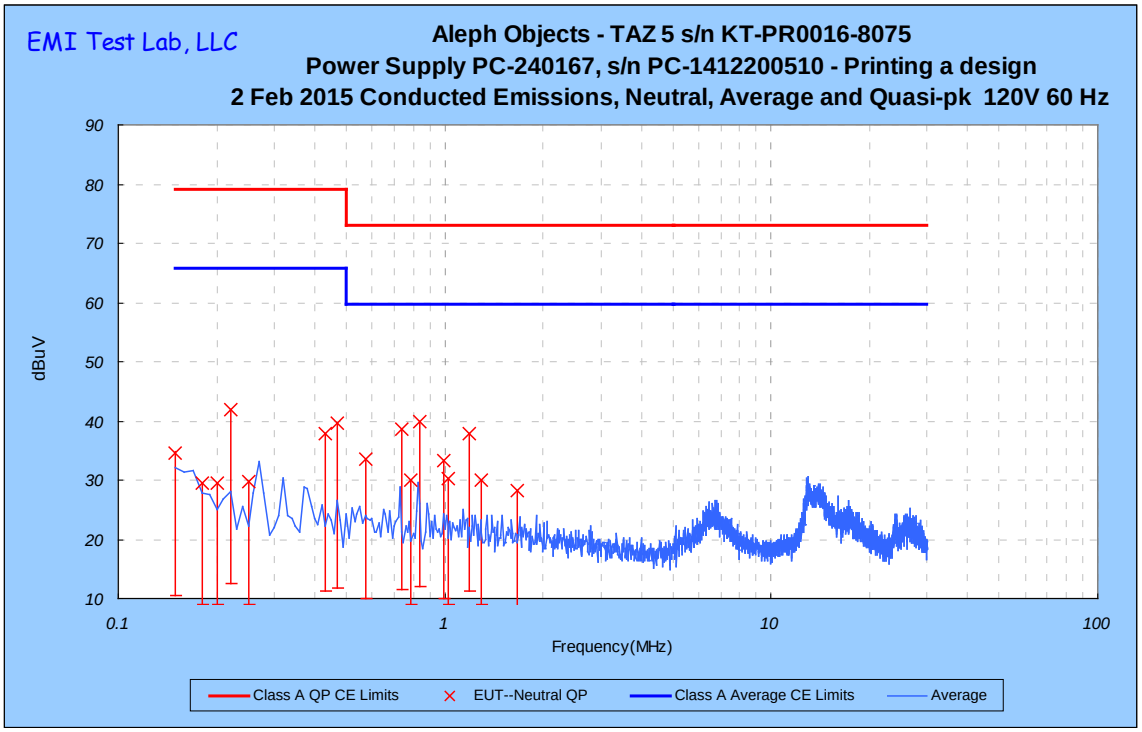
Quasi Peak passes the Quasi Peak (upper) and Average (lower) limits

Red is peak and blue is average

The above chart is corrected data;
Spectrum Analyzer reading + Cable loss + Lisn insertion loss + transient limiter

Frequency(MHz)	*QP Disturbance (dBuV)*	*QP Limit*	*Margin QP (dB)*	*Transducer Connection*	*Correction Factor (dB)*
0.150	39.10	79.00	39.90	AMN	0.20
0.280	32.94	79.00	46.06	AMN	0.24
0.430	27.58	79.00	51.42	AMN	0.28
0.690	30.13	73.00	42.87	AMN	0.53
0.840	32.41	73.00	40.59	AMN	0.71

1.090	31.20	73.00	41.80	AMN	0.90
1.190	30.51	73.00	42.49	AMN	0.91
1.700	33.92	73.00	39.08	AMN	0.92
0.200	42.31	79.00	36.69	AMN	0.21
0.225	49.32	79.00	29.68	AMN	0.22
0.250	37.43	79.00	41.57	AMN	0.23

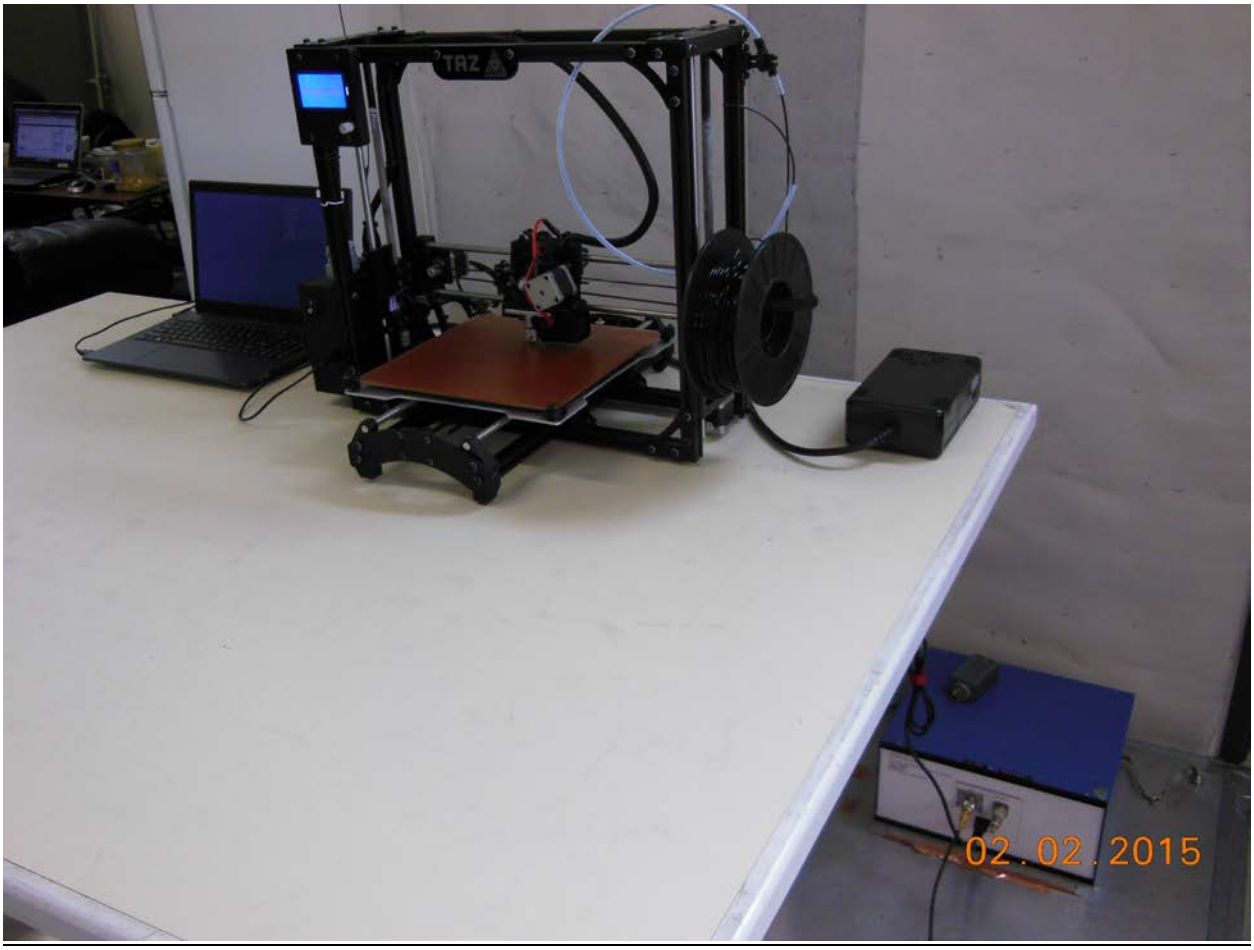


120 VAC 60 Hz Neutral

Quasi Peak passes the Quasi Peak (upper) and Average (lower) limits

Red is peak and blue is average

The above chart is corrected data;
Spectrum Analyzer reading + Cable loss + Lisn insertion loss + transient limiter



Conducted emissions test setup

2.2 Enclosure

2.2.1 30-1,000 MHz

The radiated field strength levels (electric component) have been measured in conformity with and according to the criteria as stated below.

Basic standard	:	FCC Part 15, Subpart B, ICES-003 Issue 5
Test method	:	ANSI C63.4, CAN/CSA – CISPR 22-10
Limit distance	:	3 meters
Frequency range 1	:	30 -230 MHz
Limits	:	50 dBuV/m
Frequency range 2	:	230 – 1,000 MHz
Limits	:	57 dBuV/m

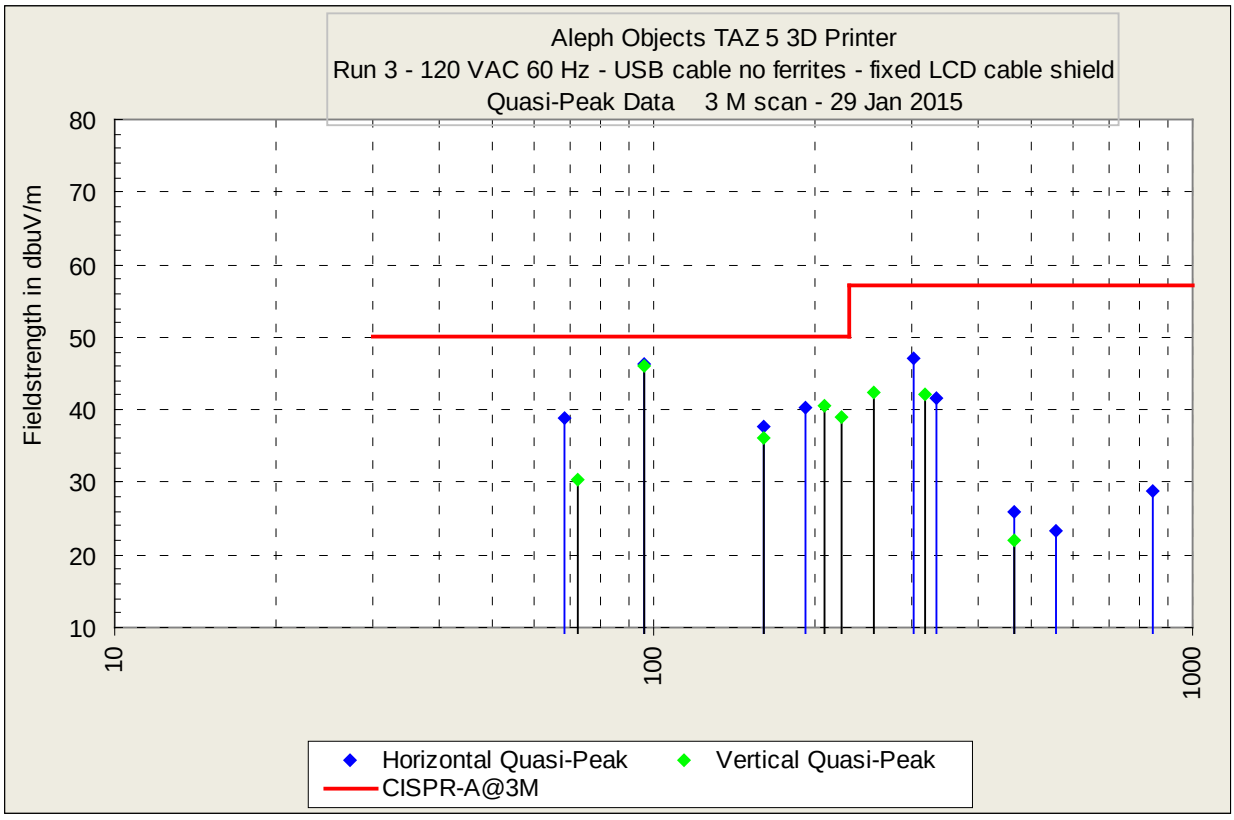
Results of the measurements concerning radiated electromagnetic fields (electric component) emitted by the EUT, enclosure, as a tested system	**PASS Class A**
Name of Test Engineer:	Dennis King
Signature:	
Date:	2 February 2015

Remarks: The configuration was tested at 120 VAC 60 Hz

Radiated Emissions Summary:

Passing Class A. The unit was re-tested and passed with a new LCD ribbon cable connector. The grounding of the LCD cable shield was also improved to pass emissions. See modifications section for details. **PASS**

The chart below is quasi-peak data compared to a quasi-peak limit



The above chart is corrected quasi-peak data;

Spectrum Analyzer reading + Cable loss + GTEM Antenna Factor – pre-amp gain

EMI Test Lab Sheet4

1822 Skyway Drive, Unit J, Longmont Co Dennis
King dennis@emitestlab.com , Cell 303-746-0611

Frequency	F.S. EUT	Limit	Azimuth	Height	Antenna Polarization	Limit delta
(MHz)	*(dBuV/m)*	*(dBuV/m)*	*Degrees*	*Meters*	*H or V*	*dBuV*
223.99	39.02	50	36.0	1	V	-11.0
467.94	22.12	57	57.0	1	V	-34.9
255.99	42.5	57	63.0	1	V	-14.5
319.98	42.12	57	129.0	1	V	-14.9
96.00	45.97	50	135.0	1	V	-4.0
159.99	36.17	50	189.0	1	V	-13.8
207.99	40.45	50	228.0	1	V	-9.6
72.03	30.30	50	351.0	1	V	-19.7
192.00	40.22	50	0.0	1	H	-9.8
68.14	38.75	50	6.0	1	H	-11.3
468.10	25.90	57	57.0	1	H	-31.1
555.83	23.37	57	117.0	1	H	-33.6
96.00	46.20	50	135.0	1	H	-3.8
159.99	37.65	50	189.0	1	H	-12.4
303.99	47.02	57	204.0	1	H	-10.0
335.99	41.62	57	207.0	1	H	-15.4
843.80	28.72	57	312.0	1	H	-28.3

2.2.2 1-6 GHz

The radiated field strength levels (electric component) have been measured in conformity with and according to the criteria as stated below.

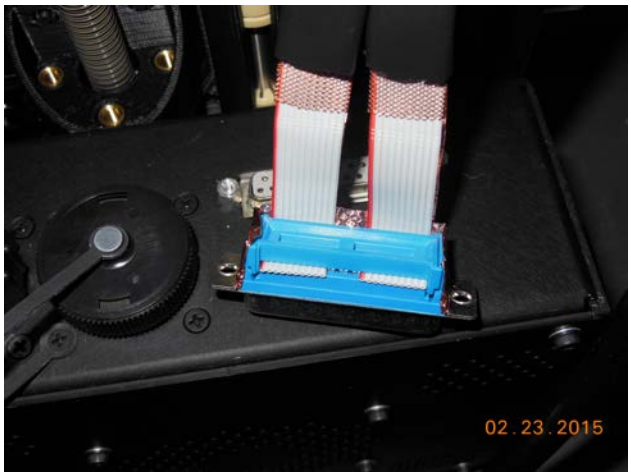
Basic standard	:	FCC Part 15, Subpart B, ICES-003 Issue 5
Test method	:	ANSI C63.4, CAN/CSA – CISPR 22-10
Limit distance	:	3 meters
Frequency range 1	:	1-3 GHz
Limits	:	Average 50 dBuV/m, Peak 70 dBuV/m
Frequency range 2	:	3-6 GHz
Limits	:	Average 54 dBuV/m, Peak 74 dBuV/m

Results of the measurements concerning radiated electromagnetic fields (electric component) emitted by the EUT, enclosure, as a tested system	**Not applicable- no clock frequency higher than 108 MHz**
Name of Test Engineer:	Dennis King
Signature:	
Date:	23 February 2015
Remarks: Not applicable , all clocks under 108 MHz.	

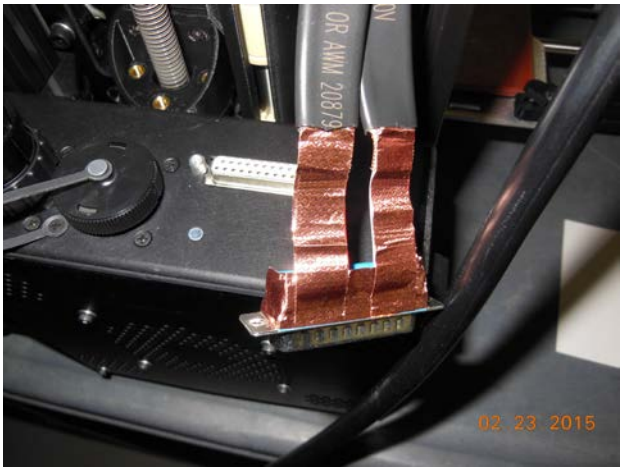
Radiated Emissions Setup

Radiated emissions test setup

3.0 Modifications



A blue LCD cable connector was used during emissions testing, changing from a more expensive version of the same connector. The results were the same or better using the less expensive connector.



Copper tape was added to the ribbon cable shielding to connect the shield to the metal of the connector in order to get a chassis ground connection.

4.0 User Guide Statements - Labels

From the FCC's CFR Part 15 Subpart B

For a Class A digital device or peripheral, the user instructions shall include the following or similar statement, placed in a prominent location in the text of the manual:

Note: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

Modifications not expressly approved by the manufacturer could void the user's authority to operated the equipment under FCC rules.

Label on the outside of the unit:

All Class A devices shall bear the following statement in a conspicuous location on the device:

This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions:

1. This device may not cause harmful interference, and
2. this device must accept any interference received, including interference that may cause undesired operation.

5.0 Test equipment and Environmental Conditions

All tests were conducted within parameters specified for each test, for example >30% humidity for ESD. The lab temperature during all testing was between 70-72 degrees F.
All equipment used for testing has been calibrated or verified for cal using NIST traceable standards. Each piece of test equipment has a cal verification procedure that is conducted before and after each test.

Table of Test Equipment

Equipment	Description and Test	Model number	Serial number	Next cal due
HP Spectrum Analyzer	Used for Radiated and Conducted Emissions	8566B	2607A02760	3 June 2015
HP Quasi-Peak Adapter	Used for Radiated and Conducted Emissions	85650A	8574A00233	3 June 2015
Advantest Spectrum Analyzer	Used for Radiated and Conducted Emissions	R3361A	01730556	20 October 2015
Com-Power transient Limiter	Conducted Emissions	HZ560	001	3 June 2015
Miteq Pre-Amp	Radiated Emissions	1381	544407	20 October 2015
RF Bay Pre-Amp	Radiated emissions – 100kHz to 10 GHz	LPA-10-20	0643	2 Dec 2015
GTEM	Radiated Emissions and Radiated Immunity	5317	9703-1209	26 April 2015 – Field Uniformity Cal per IEC 61000-4-20
3 Meter FAR – Fully Anechoic Room	Radiated Immunity and Emissions	N/A	FAR #1	15 October 2015 Field Uniformity per IEC/EN 61000-4-3 and Correlation data to GTEM
ComPower Horn Antenna	1-18 GHz – Radiated Immunity and Emissions	AH 118	071040	20 March 2016
Chase BiLog Antenna	Radiated Emissions and Immunity	CBL6111	1121	20 March 2016
Marconi Instruments – Signal Generator 10kHz – 2.7 GHz	Radiated Immunity	2031	1196061031	20 October 2015
HP Signal Generator	Radiated Immunity	8657A	STD0578	3 May 2015

HP Synthesized Sweep Generator .01-20 GHz	Radiated Immunity 1 GHz to 2.7 GHz	83752B	34462	3 May 2015
Amplifier Research .800 – 4.2 GHz Amp	Radiated Immunity – 1 GHz to 2.7 GHz	10S1G4	34516	4 May 2015
Antenna Research Associates – 100 Watt amplifier w/controller	Radiated Immunity – 80-1000 MHz in the FAR	ARAPS/PC757LC ARA757LC-CE	587V7 587V7	20 October 2015
Kalmus Power Amplifier	Radiated Immunity 150kHz – 1 GHz – in the GTEM	747LC-CE	7894-1	10 May 2015
Amplifier Research E- Field Probe	Radiated Immunity	FP 2000	12845	10 May 2015
Com-Power LISN	Conducted emissions	LI-115	241010	17 May 2015
Com-Power LISN	Conducted emissions	LI-115	241011	11 September 2015
California Instruments 1000 VA Power Source	Emissions and Immunity - used as a 100/120/230/240-VAC 50/60 Hz AC source	1001WP	L04788	4 June 2015
EMI Labs CDN	Conducted Immunity	EMICDN	001	9 Dec 2015
Schaffner ESD Gun	Electro Static Discharge	NSG435	54711	11 Dec 2015
KeyTek ECAT	Fast transients / Burst	E412	32612	5 June 2015
FCC Inc. RF Current Probe	Monitor Conducted Immunity signal	F-33-1	423	9 Dec 2015
EMI Labs Mag Loop	Magnetic Loop Antenna	Mag100	80162	12 Dec 2015
Thermo Keytek CE Master	Surge/ AC Dips and Interrupts	CE Master	0405277	15 Dec 2015

All equipment used for testing has been calibrated or verified for cal using NIST traceable standards. Each piece of test equipment has a cal verification procedure that is conducted before and after each test.

6.0 *Measurement Uncertainty* - Radiated Emissions example;

Table of Uncertainty Calculation					
√	**Contribution**	**Designation**	**Probability Distribution**	**k**	**Uncertainty (dB)**
	Equipment Under Test Uncertainties	U_{EUT}			Note 1
√	Measuring Receiver Amplitude Accuracy	$U_{RXaccuracy}$	rectangular	$\sqrt{3}$	± 0.9
√	GTEM Uniformity	$U_{Uniformity}$	rectangular	$\sqrt{3}$	± 4.0
√	Secondary Field Components	$U_{Secondary}$			Excluded by Test Method
√	Mismatch Uncertainty-GTEM to Pre-Amplifier	$U_{Mismatch}$	U-shaped	$\sqrt{2}$	+0.63 and -0.65
√	Mismatch Uncertainty-Pre-Amplifier to Spectrum Analyzer	$U_{Mismatch}$	U-shaped	$\sqrt{2}$	+0.92 and -1.03
√	System Sensitivity Error	$U_{Sensitivity}$	rectangular	$\sqrt{3}$	0.28
√	GTEM Electric-Field Frequency Response	$U_{E-Field}$	rectangular	$\sqrt{3}$	± 1.6
	Ambient Signal Uncertainty	U_{Abient}			Not Significant
√	GTEM to OATS Correlation	U_{Corr}	rectangular	$\sqrt{3}$	±1.2
√	Septum Height Variation	U_{Septum}	normal	2	+0.72 and -0.82
	Coaxial Cable Temperature Variations	$U_{CableTemperature}$			Not Significant
√	Coaxial Cable Calibration	$U_{CableCalibration}$	rectangular	$\sqrt{3}$	±0.05
√	Pre-amplifier Calibration Uncertainty	$U_{Pre-Amp}$	rectangular	$\sqrt{3}$	±0.05
	Combined Uncertainty(dB) Positive Terms				2.77
	Combined Uncertainty(dB) Negative Terms				-2.75
	Expanded Uncertainty Positive Terms		Normal	2	5.54
	Expanded Uncertainty Negative Terms		Normal	2	-5.50

Typical Measurement Uncertainty for the following Tests:

The estimated combined standard uncertainty for Conducted Emissions, CISPR 22 is ± 1.2dB
The estimated combined standard uncertainty for Radiated Immunity, EN 61000-4-3 is ± 2.7dB
The estimated combined standard uncertainty for EFT/Burst, EN 61000-4-4 is ± 5.8%
The estimated combined standard uncertainty for Surge, EN 61000-4-5 is ± 8%
The estimated combined standard uncertainty for Conducted Immunity, EN 61000-4-6 is ± 1.5 dB
The estimated combined standard uncertainty for Magnetic Fields, EN 61000-4-8 is ± 0.6%
The estimated combined standard uncertainty for Voltage Dips and Interrupts, EN 61000-4-11 is ± 4.3%
The estimated combined standard uncertainty for Harmonic current and flicker is ± 11.6%
The estimated combined standard uncertainty for ESD testing, EN 61000-4-2 is ± 4%

7.0 Test Plan

Testing required
The LulzBot TAZ 5 3D Printer will be tested for Class A Emissions per FCC Part 15 Subpart B, Class A.

Test Setup
The LulzBot TAZ 5 will be operating in a typical use mode, printing an object during all the testing.
The user software is installed on a laptop and is controlling the 3D printer. There are no other I/O cables on the 3D Printer.

Typical software that the end user would use will be used during the testing.

Failure Criteria
If the unit stops working or the printing process is altered by the injected noise, this would be considered a failure.

I/O cables
The unit has only one I/O cable, the USB cable that is used to control the printer from software installed on the host computer. There are no I/O cables on the unit 3 meters or longer.

Status of the test unit
Production level.

Power Supply used during all testing

8.0 Conclusion

The Aleph Objects – LulzBot TAZ 5 3D Printer complies with;

FCC Part 15 Class A for commercial use and Industry Canada's ICES-003 Class B, also for commercial use

in the configurations and operating modes as stated in this test report.

End of Report