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A Simple RFI "Pre-Test" for Small Switching Power Supply Units

Figure 1: Examples of the six physical types of Switching PSUs tested.

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This article describes a simple method for evaluating and comparing the Radio Frequency Interference (RFI) put out by what I will call small, switching Power Supply Units (PSUs). As we know these come in many sizes and shapes. Most are AC plug in power supply units, providing low power (35 watts or less) 12 volts DC, or 5 volt DC, USB output type power sources – also automotive "cigar lighter" plug in DC to DC units.

Some other authors have also described simplified test methods for testing PSUs without the need for the usual specialized equipment. The accepted regulatory method for evaluating RFI on AC supplied PSUs requires the use of specialized test equipment such as a spectrum analyzer and a Line Impedance Stabilization Network (LISN). The result of the test is a graph showing measured RFI levels over a wide frequency range and compared with regulatory limits, usually marked on the same graph.

Here are some key terms:

EMI – Means Electromagnetic Interference, which covers just about any kind of signal, over a very wide range and infers that it is interfering with your electronics.

EMC – Means Electromagnetic Compliance and can be a measure of how well an electronic device complies with the current Regulatory Standards, and which usually refers to both emissions and susceptibility.

RFI – Means Radio Frequency Interference and is often used interchangeably with EMI. However, RFI usually refers to a specific subset of frequencies.

Here are some facts:

1) Regulatory RFI tests are focused on conducted RFI, that is coupled back into the AC mains and which then may interfere with other mains-connected electronics.

2) There is also an RF component called radiated RFI, which is not addressed here.

3) It is well known that harmonics of the switching waveform are also coupled out to the DC output cable as well as the AC mains.

4) It is also well known that designs which mitigate and reduce mains coupled RFI, also reduce the coupled RFI on the DC output cable.

5) Except in special cases, the main switching frequency of the PSUs I have described is less than 1 MHz.

During the past year, I have been working on a project to also come up with a simple "pre-test" method, that one could use to assess and compare different PSUs for RFI by a simple means of measuring RFI on the DC output cable.

Test Units

I sifted through my collection of AC-DC and DC-DC switching adapter plug-ins, accumulated over past years, and randomly selected 24 units as typical examples to form a group of test units. These are all 5 VDC or 12 VDC output at three or less amps and most provide their DC output via a short two-wire cord with a DC "barrel" connector. The few with USB output connectors were tested using a modified USB cable, with a DC "barrel" connector on it. The serialization from one to 24 was completely at random as the samples were found.

Figure 1 above shows six of the lot which are representative of the different types of switching PSUs I tested.

Objective

Although I have a spectrum analyzer and an LISN, the prospect of performing compliance scans on 24 PSUs and then trying to compare and rank the resulting 24 scan recordings was not appealing. What I hoped to find was some other measurement tool and/or method that would ideally give a single "no-nonsense", quantitative reading that could then be used to classify a PSU's likelihood for being "RF" quiet", "RF noisy", or somewhere in between.

In the end, I found that my "older" Tenma 72-6603 AC millivoltmeter (Figure 2 on the next page) seemed a good fit for the job. It has a 3 db bandwidth of 20 Hz to 1 MHz and a full scale measurement range of 300uV to 100V AC.

Figure 2: Tenma AC Millivoltmeter used for ripple/noise measurements.

Most of these small PSU's have a fundamental switching frequency in the area of 50 kHz to 150 kHz, but may generate strong harmonics up to and well beyond 1 MHz. We are focused on the strongest harmonics which are mostly less than 1 MHz and which will be captured and averaged by the Tenma AC miilivoltmeter.

Measurements

Table 1 (Figure 3) summarizes the measurements that I have taken from the DC outputs of the 24 randomly selected switching PSUs. Measurements were done where possible at a 1 amp DC load, as it was observed that RFI is considerably higher when the PSU is loaded.

Average ripple and noise was measured with the Tenma 72-6603 AC millivoltmeter, whereas peak-to-peak ripple and noise was measured with a Hantek 5202P DSO using a 10x probe with a BNC adapter.

The Hantek oscilloscope and the Tenma meter were parallel connected to the test box Vout BNC using a BNC "T" connector. See Figure 4 on the right.

For easy comparison, you will see in Table 1 that I have sorted the measurement data on the average ripple and noise column, from minimum to maximum.

Figure 3: Table 1 – Measurement data Summary

Table 1 - Ripple and noise Measurements				Measured on DC Output				
UUT#	**Make**	**Model #**	**Rated Volts/Amps**	**Output Voltage @ 1 amp**	**PP Ripple & Noise, @ 1 amp, mV**	**AVG Ripple & Noise, @ 1amp, mV**	**Style**	**Type/Notes**
1	Challenger	PS 2.1-12	12v/3A	12.0	16	2	pl	brick
4	Egston	N2UFW3	12v/2A	11.7	15	3	pl	medical
13	--	XPJ-05C	12v/2A	12.0	50	3	pl	open pcb module
7	Intertek	Y18FF-12	12v/1.5A	11.7	60	18	pl	
8	LPL ?	20120	12v/1A	11.6	138	20	pl	GPS-do
14	Orico	PLP-E120	12v/2.5A	12.1	85	25	pl	
5	FM	FM-120-12	12v/10A	13.5	230	30		enclosed chassis
9	--	1210	12v/1A	11.9	260	41	pl	
11	--	1210	12v/1A	11.7	280	51	pl	
10	--	1210	12v/1A	11.3	230	55	pl	
6	Ho:OTO	ADS-2AM12	12v/1A	11.9	320	56	pl	
15	--	S-24-12	12v/2A	12.3	135	58		enclosed chassis
16	Umec	UPO121A	12v/1A	11.9	300	95	pl	
12	--	LYW-1205	12v/0.5	11.8	700	110	pl	@0.3A
3	Chang	1238	12v/1A	10.1	1040	200	pl	
2	Chang	1238	12v/1A	10.3	1200	220	pl	
Below units are 5V usb output								
21	Shenzen…	XHDQC3.0	5v/2A	5.00	100	12	usb	Amazon fst-chg
22	--	--	5v/3.1A	4.80	50	12	usb	cig. plug (dc-dc)
23	--	YY-22	5v/2.1A	4.80	75	15	usb	cig. plug (dc-dc)
18	I.T.E.	..500050	5v/0.5A	5.19	125	38	usb	Behringer 302
24	--	Tech 1	?	5.04	150	40	usb	cig. plug (dc-dc)
17	Samsung	EP-TA200	5v/2A	4.94	200	50	usb	fast-chg
20	--	3usbchr	5v/3.1A	5.33	250	85	usb	
19	--	BB-520	5v/2A	5.29	600	200	usb	

"pl"= dc plug, wire lead

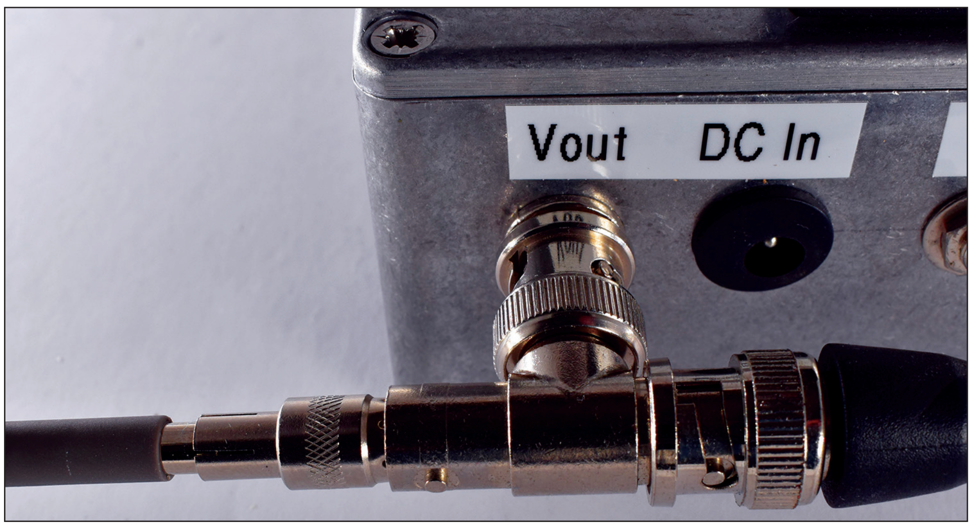

Figure 4: BNC "T" connection, with 10x Scope probe on left and 12" of RG-174 on the right to the Tenma mV meter input.

Test Box

Figure 5 on the right shows the DC load test box I constructed in order to minimize variability in the connection of the measurement devices and the PSU under test.

Figure 5: Load test box with external DC Voltmeter on top.

Figure 6 on the right shows the schematic. Three toggle switches allow selection of 0.3 to 2.3 amp loads by switching in one or all three test loads.

The Vout BNC test signal is taken from the PSU DC "barrel"connector via a 1.25 uF 160V capacitor to block DC from the measurement devices inputs.

A small LED DC voltmeter module was also affixed to the test box to verify that the particular PSU under test was indeed alive and functioning properly.

Review of Test Results/observations

1) It is interesting that the magnitude of the peak-to-peak oscilloscope measurements for the most part closely follow the order of the Tenma average AC ripple/noise measurement values.

2) Alternative AC millivoltmeters similar to the Tenma 72-6603 were made by several manufacturers like Leader, Heathkit, and Hewlett Packard, and may be found on various used equipment websites such as eBay. I note that some Chinese online sellers even offer new instruments, looking very clone-like.

3) During the course of my investigation, I often found it necessary to remeasure some or even all of the test group. I found that the average ripple/noise measurements were reasonably repeatable, whereas the peak-to-peak (PP) scope ripple/noise measurements were less so. The reason for this is not known, but it may be partly due to the differing lengths of DC output cable on each unit and that I did not particularly control the DC output cable position during testing.

4) Both units 1 and 4 measured without question the lowest ripple and noise of all 24 units. This is not surprising as both were properly marked with and/or referenced UL file numbers, FCC and CE marks. Figure 7 shows measured output RFI on the Hantek oscilloscope.

5) For comparison, unit #2 measured the highest ripple and noise of all 24 units. Figure 8 shows measured output RFI on the Hantek oscilloscope. Surprisingly, this PSU was marked with the CE and the Chinese CCC mark – China Compulsory Certificate. You may draw your own conclusions!

Conclusions

It is clear that among the group of assorted PSUs there is significant measured ripple and noise levels on the DC outputs and that measurement of these levels provides a means of comparison. The difficulty comes where one tries to relate these resulting average or PP ripple and noise values as being typical of a PSU being "RF quiet", "RF noisy" or somewhere in between.

At this time, and interpreting the data available, the best I can do would be to suggest the following classification based on the average ripple and noise measurements:

- RF quiet < 20mV
- RF noisy > 100mV

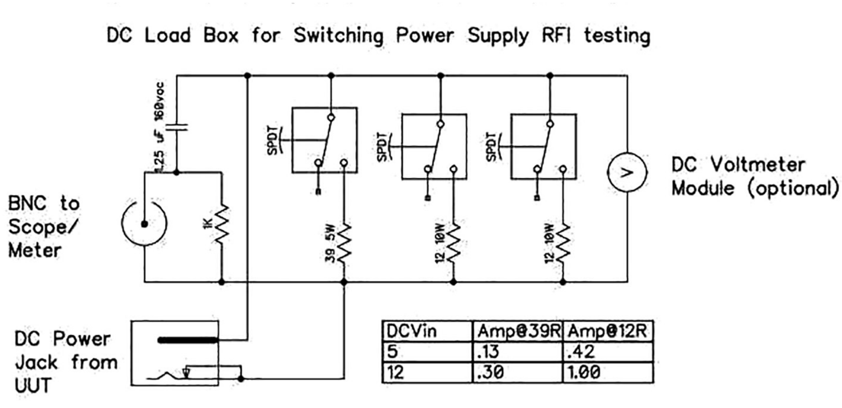

Figure 6: Load test box schematic.

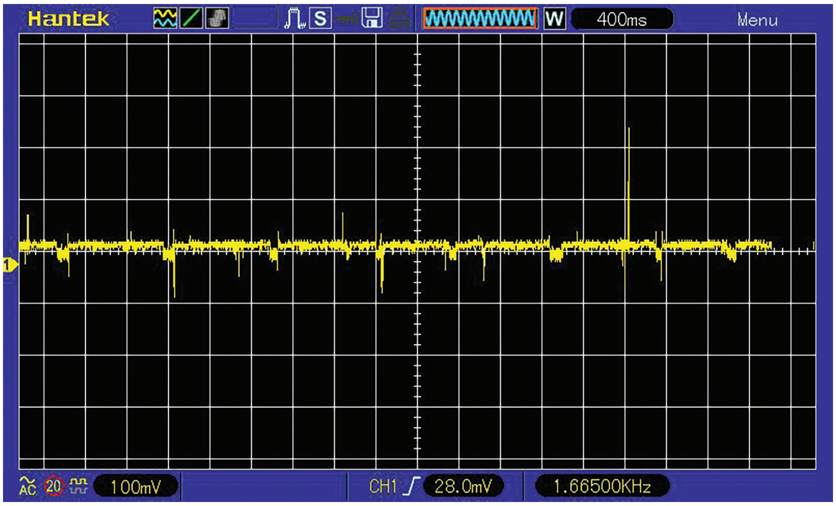

Figure 7: Oscilloscope screen showing measured RFI on unit #1 (best).

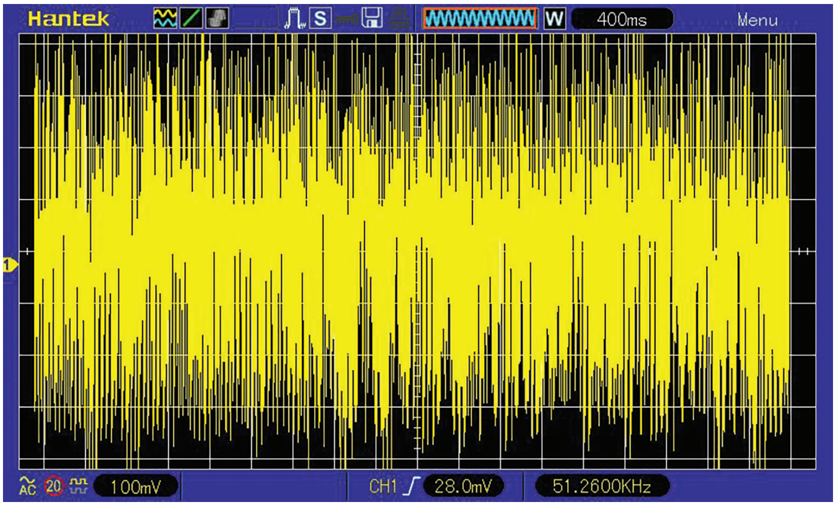

Figure 8: Oscilloscope screen showing measured RFI on unit #2 (worst).

Don Dorward, VA3DDN, has had 43+ years experience in the electronics industry including vacuum tube manufacturing, semiconductor and component testing, R&D, ISO Quality Systems, Regulatory Affairs, UL/CSA/EU/CE/EMC compliance, Environmental testing, Standards & Calibration.

Don has been an Amateur Radio operator since 2002. He is a Life Member of the Institute of Electrical and Electronics Engineers (IEEE) and is a member of the American Radio Relay League (ARRL), Radio Amateurs of Canada (RAC) and the Radio Society of Great Britain (RSGB). He can be reached at va3ddn@myrac.ca.