

Low Leakage Current Xgen

Abstract: This application note describes the adjustments that must be carried out on the medical range of Xgen six-slot powerPacs in order to reduce the leakage current so that two powerPacs can be used in parallel, while maintaining an EMC performance that complies with the Class A limits of the EN55022 standard.

Electromagnetic Compatibility (EMC)

The electromagnetic compatibility (EMC) of an electrical device is a measure of its ability to function sufficiently well in its electromagnetic environment without generating unintentional interference to the other equipment in the system. An interference source may generate conducted or radiated electromagnetic energy, i.e. conducted emission (CE) or radiated emission (RE). In this application note we will concentrate on conducted emission.

As well as being obliged to ensure that these electrical devices produce very little electromagnetic disturbances to their surroundings (emission), according to standards, manufacturers of electrical devices are also obliged to sufficiently protect their devices from electromagnetic disturbances (immunity). Both of these requirements are achieved through the use of an electrical filter. X and Y capacitors are frequently used components in electrical filters.

X and Y Capacitors

There are two forms of possible conducted disturbances, differential mode and common mode.

Differential Mode

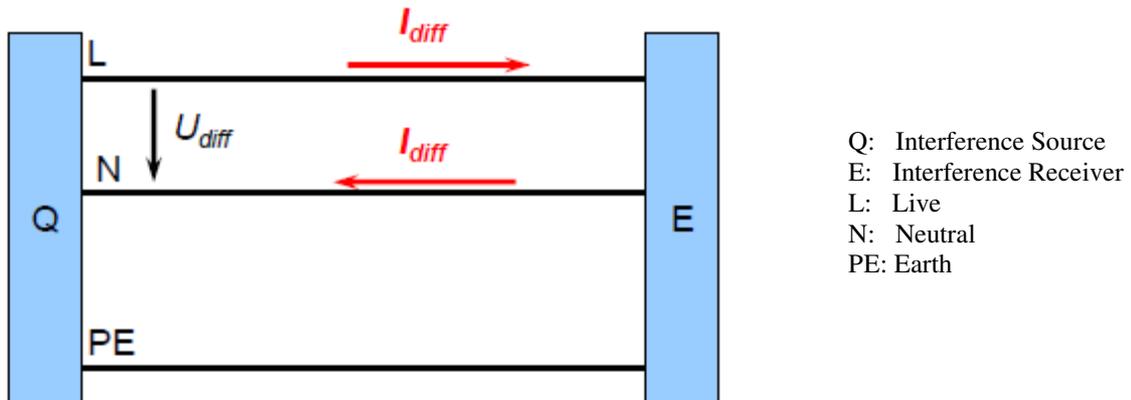


Figure 1: Differential Mode Disturbances

Differential mode disturbances flow via the live line to the interference receiver and via the neutral line back to the interference source. Differential mode disturbances can be quantified by measuring the voltage between the live and neutral conductors. Differential noise mainly occurs at relatively low frequencies (up to several hundred kHz)

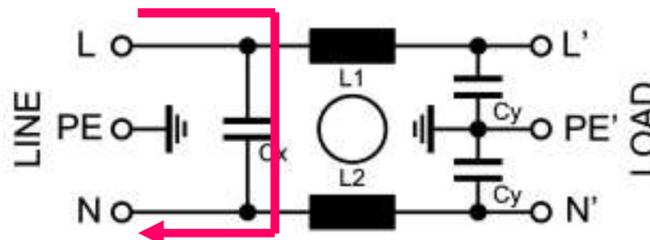


Figure 2: Filtering Differential Mode Disturbances

The use X-capacitor (between the live and neutral lines) dampens differential mode disturbances between live and neutral. It does this by acting as a short circuit for high frequency noise.

Common Mode

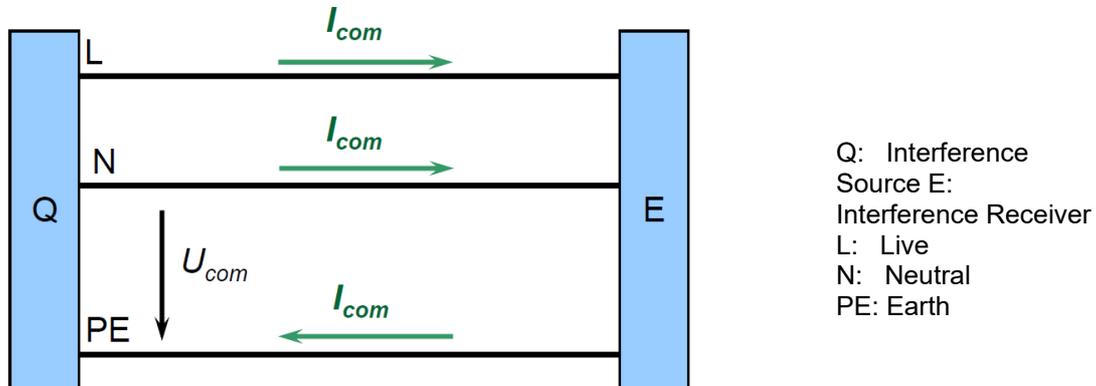


Figure 3: Common Mode Disturbances

Common Mode Disturbances flow via the live / neutral line to the interference receiver and via ground back to the source of interference. Common mode noise can be quantified by measuring the voltage between the live / neutral and earth. Common mode noise occurs mainly at high frequencies (1 MHz upwards).

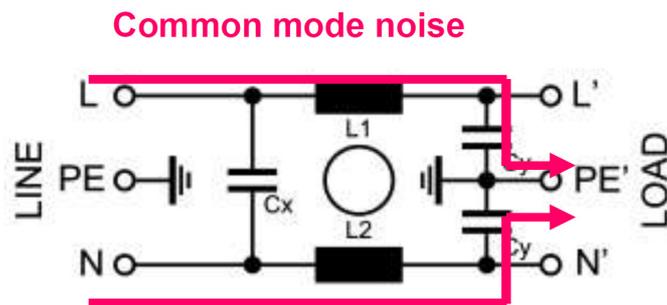


Figure 4: Filtering Common Mode Disturbances

The Y-capacitor dampens common mode noise between live / neutral and earth. For high frequency energy that comes simultaneously on both lines, the capacitors act as a short circuit to ground.

Y-capacitor capacitance must be limited in order to limit leakage current; the higher the capacitance, the greater the leakage current. Leakage current can be reduced by reducing the Y capacitor's value, but this has the unwanted knock on effect of increasing common mode noise.

Leakage Current

Leakage current is a direct function of the line-to-ground capacitance value. The larger the capacitance, the lower the impedance to Common Mode currents and the greater the Common Mode Disturbance rejection. Therefore, leakage current can also be thought of as a measure of filter performance.

However, there is a maximum value placed on this leakage current in order to limit the magnitude of expected ground return currents. The line-to-ground capacitance (or Y-capacitors) provide a path for the Common Mode current to flow to the chassis. As long as the equipment is grounded, these currents will flow in the ground circuit and present no hazard. However, if the ground circuit is faulty, the earth connection may be established by the body of a person. If this should occur, the maximum leakage current specification limits the ground return current to a safe limit.

The Xgen Power Supply and Leakage Current

With a given supply voltage and frequency, the leakage current depends solely on the capacitors C_{YL} (Live to Earth) and C_{YN} (Neutral to Earth). The total amount is given by the equation

$$I_{leak} = C_Y V$$

For a filter with a C_Y of 2.2 nF (Xgen medical power supplies), an input voltage of 230 V at 50 Hz, and factoring in a tolerance of +/- 20% the expected leakage current can be calculated as:

$$= 2 * 3.14 * 50 * (2.2 * 10^{-9} * 1.2) * 230 = 190 \mu A$$

The medical range of Xgen power supplies has a measured leakage current of around 240 μA . (The limit for medical power supplies is 300 μA). The additional leakage current can be attributed to stray capacitance between the Live / Neutral lines and Ground, which acts in parallel to the capacitance of the Y caps. This stray capacitance is responsible for approximately 50 μA of leakage current.

If we want to use two Xgens in parallel (say in an N+1 redundancy scheme), we must half the leakage current. We can do this by sufficiently reducing the Y-capacitance (since we cannot adjust the input voltage or frequency). It should also be remembered that the leakage current due to the stray capacitance will remain the same. If the Y-capacitors of 2.2 nF are replaced with Y-capacitors of 470 pF, and the calculations repeated, we get:

$$I_{leak} = C_Y V$$

$$= 2 * 3.14 * 50 * (0.47 * 10^{-9} * 1.2) * 230 = 41 \mu A$$

Add in the additional 50 μA from the stray capacitance and we would expect a leakage current of around 91 μA . (Actually measured at 96 μA). Thus, two supplies used in parallel would have a combined leakage of around 180 μA at 230 V, less than the medical standard limit of 300 μA .

But we must remember that reducing the leakage like this will have a knock on effect on the level of common mode noise.

If we measure the conducted emissions on the AC inlet of two Xgen power supplies with the 470 μA capacitors operating in parallel, we get the following results:

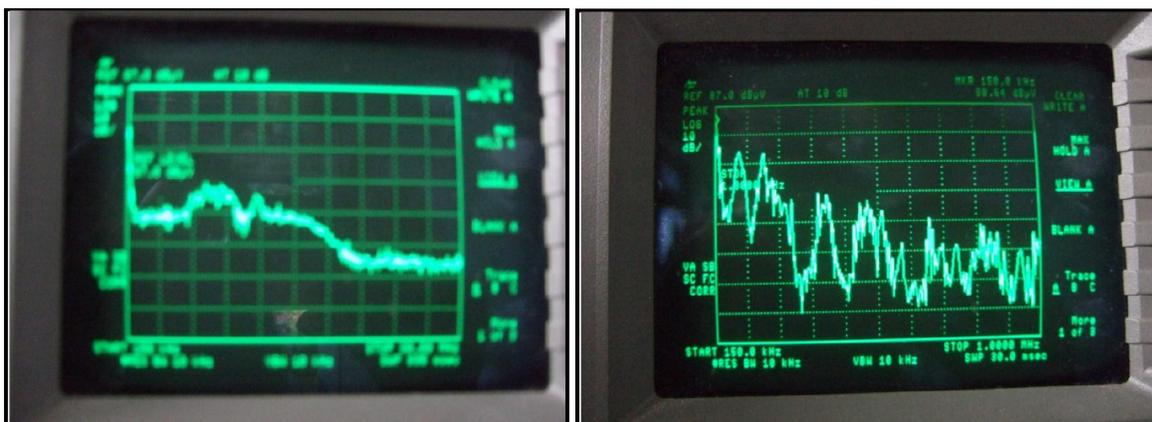


Figure 5: Left – 150 kHz to 30 Mhz, Right – 150 kHz to 1 Mhz

Frequency	Line1 dB μ V		Line2 dB μ V		Limit dB μ V	
	QP	Avg.	QP	Avg.	QP	Avg.
150.57 kHz	80	73.8	-	-	79	66

Table 1: Conducted Emissions – Line 1 (Fail)

The low leakage power supply now fails Class A limits (EN55022) for QP and Average readings. If it is to pass the Class A limits, we need to improve the filtering of common mode noise without increasing the Y-capacitance which would increase the leakage current. An alternative to the Y-capacitor is to use a common mode choke.

Common-mode chokes are designed to pass differential currents while blocking common-mode currents. This type of coil is produced by winding both supply wires on one single ferrite core.

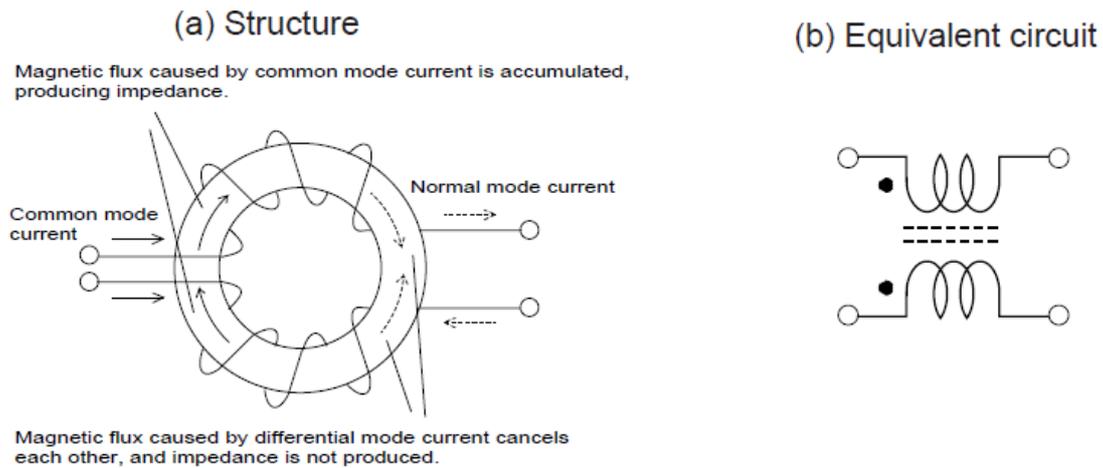


Figure 6: Common Mode Chokes

Since magnetic flux flows inside the ferrite core, common mode choke coils work as an inductor (and act as an impedance) against common mode current. An ideal common-mode choke is perfectly transparent to every mode except the common mode. It offers no resistance (or reactance) to any differential or transmission line current, but for common mode current it looks like an open circuit.

Two common mode chokes were tested with the parallel Xgen setup, with the following results:

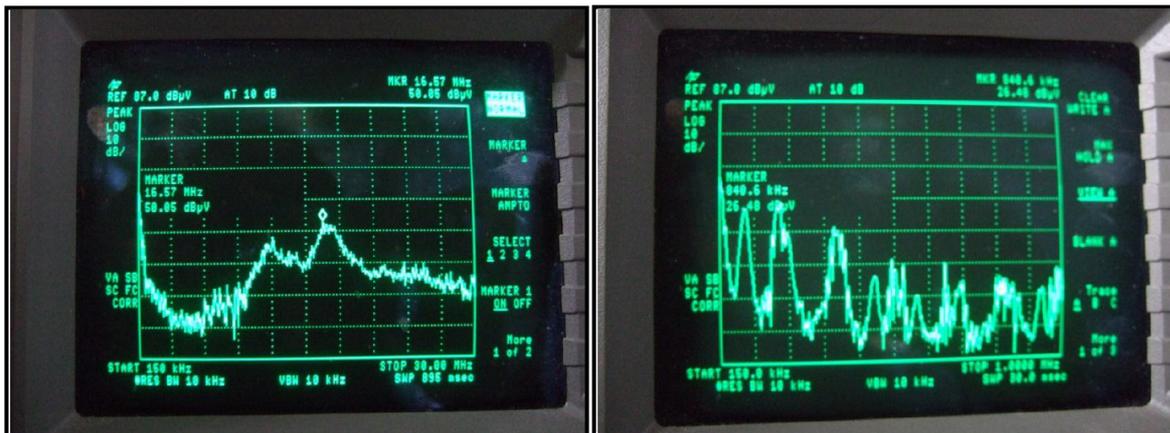


Figure 7: Left – 150 kHz to 30 Mhz, Right – 150 kHz to 1 Mhz. Vacuum Schmelze X018-80S304

Frequency	Line1 dBuV		Limit dBuV	
	QP	Avg.	QP	Avg.
150 kHz	69.4	62.7	79	66
284.1 kHz	57	52		
207 kHz	60	59.8		

Table 2: Conducted Emissions - Line 1 (Pass)

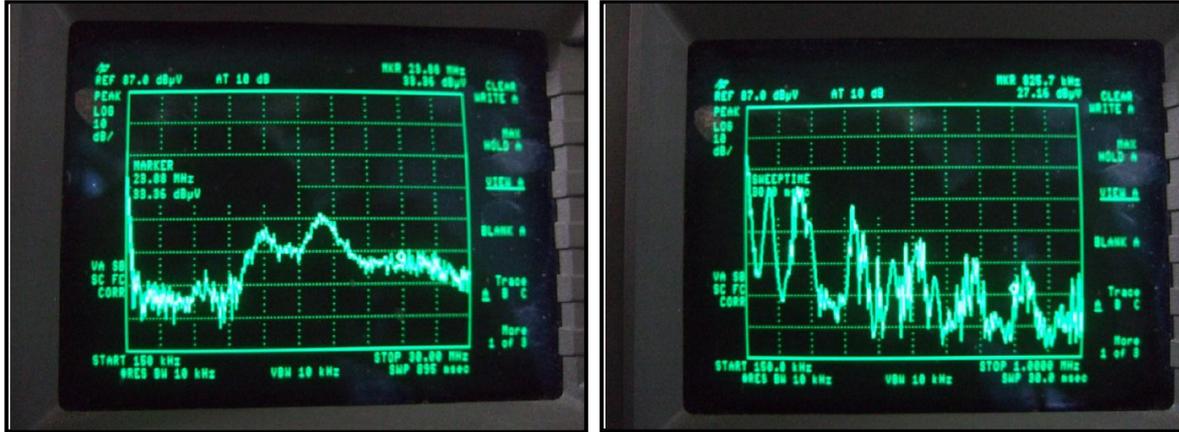


Figure 8: Left – 150 kHz to 30 Mhz, Right – 150 kHz to 1 Mhz. Würth Inductor 7446823003

Frequency	Line2 dBuV		Limit dBuV	
	QP	Avg.	QP	Avg.
150 kHz	70.4	63.4	79	66
16.65 MHz	40.4	36		
207 kHz	61	60		

Table 3: Conducted Emissions – Line 2 (Pass)

Both tests resulted in a pass for Class A EMC limits (EN55022) and medical rated leakage current.

The 4-slot version low leakage Xgen model (470 pF Y-caps) has a leakage current of around of 80 uA at 230 Vin, and does not require any additional filtering to pass Class A limits (EN55022)

Xgen Power Pac	Description	Max Leakage Current
XM Series	Standard Xgen Medical 4-Slot	300uA
XV Series	Standard Xgen Medical 6-Slot	300uA
XM Series - with 04 low leakage current option	Standard Xgen Medical 4-Slot	150uA
XV Series - with 04 low leakage current option	Standard Xgen Medical 6-Slot	150uA

The Advanced Energy portfolio has a range of products available to the user to provide a solution for whatever the application requirements may be.

With output power levels from 200 W to 1340 W, the Xgen series of User configurable modular power supplies provide high efficiency, high reliability power solutions for Medical, Industrial, Communications and HI-Rel applications. For more information and copy of our catalog, please contact Advanced Energy.

References

- [1] Schurter Electronic Components, "Introduction to EMC", www.schurterinc.com
- [2] TE Connectivity, "Understanding Leakage Current", www.te.com.
- [3] Exergia, "Differential and Common Mode Noise", www.Exergia.info
- [4] Chuck Counselman, "Common Mode Chokes", www.yccc.org

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