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](image1)

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](image2)
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**

![Common Mode Diagram](image)

Q: Interference Source  
E: Interference Receiver  
L: Live  
N: Neutral  
PE: Earth

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).

![Common Mode Noise](image)

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

$$I_{\text{leak}} = \omega C_Y V$$

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:

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

The medical range of Xgen power supplies has a measured leakage current of around 240 $\mu$A. (The limit for medical power supplies is 300 $\mu$A). 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 $\mu$A 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:

$$I_{\text{leak}} = \omega C_Y V$$
$$= 2 \times 3.14 \times 50 \times (0.47 \times 10^{-9} \times 1.2) \times 230$$
$$= 41 \mu A$$

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

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 $\mu$A capacitors operating in parallel, we get the following results:

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Line1 dBAV</th>
<th>Line2 dBAV</th>
<th>Limit dBAV</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>QP</td>
<td>Avg.</td>
<td>QP</td>
</tr>
<tr>
<td>150.57 kHz</td>
<td>80</td>
<td>73.8</td>
<td></td>
</tr>
</tbody>
</table>

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

![Common Mode Chokes](image)

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:

![Common Mode Choke Test Results](image)

Figure 7: Left – 150 kHz to 30 Mhz, Right – 150 kHz to 1 Mhz. Vacuum Schmelze X018-80S304
Table 2: Conducted Emissions - Line 1 (Pass)

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Line1 dBμV QP</th>
<th>Line1 dBμV Avg.</th>
<th>Limit dBμV QP</th>
<th>Limit dBμV Avg.</th>
</tr>
</thead>
<tbody>
<tr>
<td>150 kHz</td>
<td>69.4</td>
<td>62.7</td>
<td>79</td>
<td>66</td>
</tr>
<tr>
<td>284.1 kHz</td>
<td>57</td>
<td>52</td>
<td></td>
<td></td>
</tr>
<tr>
<td>207 kHz</td>
<td>60</td>
<td>59.8</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3: Conducted Emissions – Line 2 (Pass)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>150 kHz</td>
<td>70.4</td>
<td>63.4</td>
<td>79</td>
<td>66</td>
</tr>
<tr>
<td>16.65 MHz</td>
<td>40.4</td>
<td>36</td>
<td></td>
<td></td>
</tr>
<tr>
<td>207 kHz</td>
<td>61</td>
<td>60</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

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 80 μA at 230 Vin, and does not require any additional filtering to pass Class A limits (EN55022)

<table>
<thead>
<tr>
<th>Xgen Power Pac</th>
<th>Description</th>
<th>Max Leakage Current</th>
</tr>
</thead>
<tbody>
<tr>
<td>XM Series</td>
<td>Standard Xgen Medical 4-Slot</td>
<td>300μA</td>
</tr>
<tr>
<td>XV Series</td>
<td>Standard Xgen Medical 6-Slot</td>
<td>300μA</td>
</tr>
<tr>
<td>XM Series - with 04 low</td>
<td>Standard Xgen Medical 4-Slot</td>
<td>150μA</td>
</tr>
<tr>
<td>leakage current option</td>
<td>Standard Xgen Medical 6-Slot</td>
<td>150μA</td>
</tr>
<tr>
<td>XV Series - with 04 low</td>
<td>Standard Xgen Medical 6-Slot</td>
<td>150μA</td>
</tr>
</tbody>
</table>
The Excelsys 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 200W to 1340W, 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 catalogue, please contact sales@excelsys.com, or for North America and Canada salesusa@excelsys.com

Alternatively, please visit our website at www.excelsys.com to download our catalogue and learn more about the Xgen.

References


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