DC/DC converters for Medical Applications

“Medical grade DC/DC converters” is an often used, but more often abused, description of a class of converters that are increasingly in demand. What are actually the particular requirements that medical applications place on DC/DC converters? This seems a simple question which should have a simple answer, but this is unfortunately not the case. Probably only the end user can answer this question because the requirements and restrictions are as diverse as the medical applications in which they are used. However, if we look through the questions and answers that arise during the daily customer technical support and design-in work that RECOM Technical Support does, we can offer some guidelines:

Isolation - the yardstick by which all things are measured

The main requirement that almost all specifications for converters appropriate for use in medical applications have in common is the search for as safe as possible galvanic separation between the input and output, usually expressed as a high as possible isolation voltage. The ability of an isolated converter to withstand high voltages across its isolation barrier is dependent on the materials used to construct the converter, the physical separation between the input and output tracks on the internal PCB and the ability of the isolation transformer to withstand the electrical stress between input and output windings. Consequently, the two most essential points that decide the suitability of a DC/DC converter for medical applications are the transformer construction and the internal construction of the converter. This second point is important because the medical standards define creepages and clearances in air which do not translate 1:1 to the separations used in most DC/DC converters which are potted and filled with a homogenous epoxy mass which excludes air, therefore it is still acceptable to have internal separations which are smaller than the limits given by the standards. This important fact also helps bridge the gap between meeting the requirements of the standards and manufacturing a converter which is as small as possible to fit into the increasingly restricted space available on most circuit boards – if this was not so, the size of medical grade converters would be unacceptably large for many applications. Now to the essential part: the construction of the transformer in order to meet the requirements for high voltage isolation. Here, there are also several different solutions available. The simplest and mostly commonly applied solution is to use windings with as thick as possible coating of lacquer or with multiple coatings of lacquer to ensure adequate isolation. However, as the trend towards miniaturisation progresses, this solution is reaching its limits as input and output windings have to wound directly over each other to save space. Also, small diameter toroidal transformers, like the ones usually used in low power small size DC/DC converters, have a very tight bending radius which could lead to a thinning of the lacquer coating due to the mechanical stress placed on the wires during the winding process, which in turn could compromise the electrical isolation. Thus this method of construction reaches a limit of isolation strength of around 4kVDC applied for one second, which translates to a continuous working voltage of approximately 1.8kVDC.

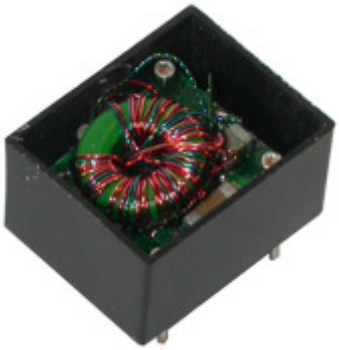

Figure 1: Simple DC/DC transformer construction for isolation of up to 4kVDC/1 Second.
(For a High-Res-Photo, please click on the image!)

Nevertheless, isolation voltages higher than 4kVDC/ 1 second are possible. For example Recom product series like the RP family with 5.2kVDC/1 second or the RxxPxx and RxxP2xx converters with 5.2kVDC/1 minute (which corresponds to about 6.5kVDC/1 second) and the RV-xxxx with 6kVDC/1 second all have small case sizes, but use a different technique to achieve these very high isolation figures. RECOM is one of the few manufacturers that have perfected the two chamber transformer system. Each winding is therefore wound separately on to the transformer and therefore the isolation is not wholly reliant on the thickness of the lacquer as there is in addition a physical separation between the wires. There are also two different techniques that can be used, either separation by means of separation-bridge (see Picture 2a) or the application of a pot system, in which one winding is wound directly around the toroidal kernel which is placed within a non-conductive annular plastic pot and covered with a lid so that the transformer core and primary winding are entirely encased. The secondary winding is then wound annularly around this whole construction (see Picture 2b). This method is a very labour intensive method of constructing a transformer, but delivers excellent results in a sub-miniature size.

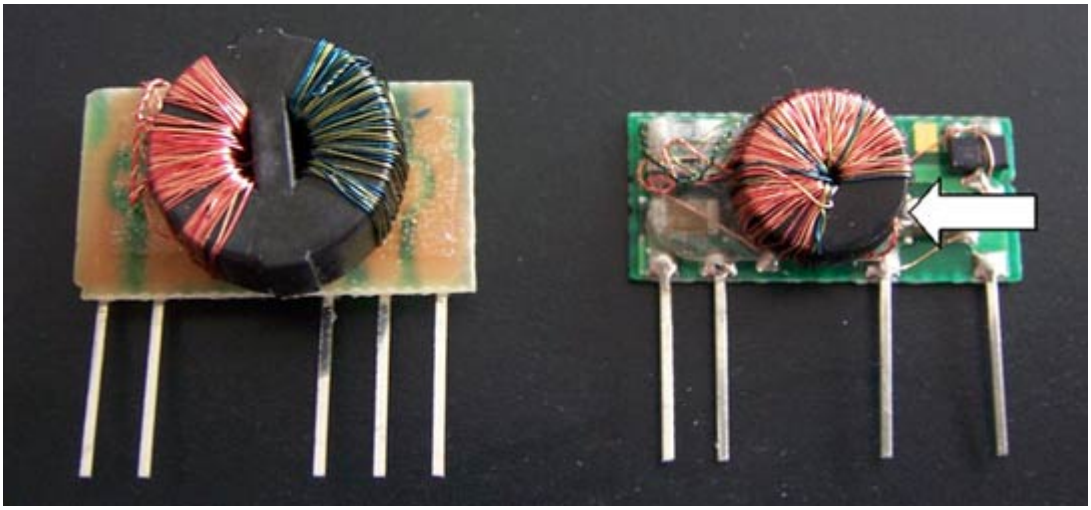

Figure 2: Two chamber-systems, either with Separation Bridge or Pot-System (wires leading to the internal core can be seen entering at the lower right of the encased transformer).
(For a High-Res-Photo, please click on the image!)

Both the separation bridge and pot-system solutions deliver excellent conversion efficiency, but efficiency is rarely a major criterion in medical applications. The main and much more important advantage is that isolation strength is not dependent wholly on the thickness of the lacquer and therefore thinner wires coated with tougher lacquer can be used with this form of the transformer construction which in turn reduces the danger of inadvertent damage to the lacquer during the hand-winding process and in turn leads to a higher quality and more consistent quality stability in the manufacturing process. Furthermore, the coupling capacitance between input and output (a parasitic feature of all transformers) is substantially reduced to typically only 4pF – an exceptionally low value that helps increase performance. These two transformer construction techniques are most often found in unregulated 1W or 2W DC/DC converters, as higher power converters generating 3W or more usually use correspondingly larger and more robust transformers which can be machine wound. The case size must then be increased to typically a DIP24 package size which has become an industry standard, although often available in at least three different pinout configurations. The transformers used in these higher power converters are no longer toroidal but typically partially pre-fabricated bobbin-type designs with larger coil diameters. Consequently multiple layers of windings can be wound without concern about stressing the wires or damaging the wire insulation, which means that often the necessity of an

isolating tape or foil between primary and secondary windings is not required. An insulation foil between windings is typically only required if the insulation requirement is equal to or exceeds 4kVAC for 1 minute or 8kVDC for 1 second.

Figure 3: Bobbin-type machine-wound transformer construction in a DC/DC converter.
(For a High-Res-Photo, please click on the image!)

Are datasheets and certificates a guarantee of the product specifications?

Some salesmen will say almost anything to win a sale, as many “facts” are easy to claim when they are undocumented. However, even written datasheets can be carefully prepared as to document only one version of reality. This is especially t rue when it comes to specifying the isolation of converters and creative “specmanship” is unfortunately a daily occurrence in the DC/DC converter business. Certain essential qualifications such as the length of time a high voltage can be placed across a converter or whether the voltage is AC or DC are often omitted, as the naked figures then quoted can seem much more impressive. A quasi-standard is that isolation figures are declared as a DC voltage applied for 1 second, but the test regime should always be given in the datasheet to make certain. RECOM datasheets declare the isolation values as the DC voltage that the converter will withstand for either one second or one minute, depending on the converter type. In addition, every converter is tested at least twice during production to 100% guarantee that the values given are a minimum value. RECOM’s Application Notes also give more information to work out equivalents between AC, DC or continuous working isolation and to translate between isolations quoted for one second or one minute. For example, a converter rated for 3kVDC/1 sec will only withstand 1.5kVAC/1 minute due to the extra stresses placed on the isolation barrier by the AC waveform.
Self certification is one thing, but a true test is to have a third party check and validate your results. There are many certification and test houses that will independently test your converters to ensure conformity with the relevant standards. Again however, a careful reading of the specification sheet is often rewarding. If a converter is “designed to meet” a particular standard, it is by no means certain that it has actually approved to that standard. This phrase means only that the converter was designed to meet the relevant norms given in the standard and although internal test reports may even “prove” that this is the case, unless an independent third party authority has also been willing to issue a certificate and a test-report, there is no final certainty. However, even a formal test report often holds surprises. From our own market experience, we have often seen such succinct sentences written in test reports such as “no separation between primary and secondary is needed” and therefore the isolation test is “Not Applicable”. This situation arises because the converter has been presented to the test house as a safe extra low voltage (SELV) device that cannot produce dangerous voltages and so does not even need to be tested for galvanic isolation. The test house follows the instructions given by the client and prepares a perfectly valid but ultimately unhelpful test report and certificate.
A short communication with the manufacturer often saves much misunderstanding and inconvenience later. And indeed, such requests from customers for technical support with medical safety norms such as EN-60601-1 or UL-60601-1 certification are nowadays much more frequent than with the more

universal safety standard EN-60950 or UL-60950 to which almost every competent DC/DC manufacturer has had their products certified. Every RECOM medical standard certificate is accompanied with a test report which details the testing protocols.
Therefore, a vital quality criterion that should be used to select a manufacturer is the level of technical support. Can such pitfalls mentioned above be avoided by the manufacturer giving clear and unambiguous information? Are certificates available for inspection and do they come with the all-important substantiating test reports? Such questions should and must be asked by all designers working in critical applications such as in the medical field.

Further critical specifications

Besides isolation strength, the next most critical specification for DC/DC converters is the operating temperature range. The usual definition of operating temperature range is the range of ambient air temperatures that the converter can be used in under full load without using fans to force-cool or heating pads to pre-warm the converter. An efficient converter with low internal power dissipation can work at high temperatures without overheating and well designed converter will start reliably at very low temperatures. Combining these factors gives a derating graph which shows over what temperature range the converter will work with full load and by how much the load must be reduced at high temperatures to compensate for the internal heat generated by the converter. The requirement for adequate cooling can influence the board spacing for higher power converters because as the power density increases, so must the clearances between the converters when mounted on the board be more carefully controlled to leave adequate room for air to circulate freely. Again, some care is required concerning specmanship. Some manufacturers quote case temperature instead of ambient air temperature so as to give results that are 10-15°C higher, some define ambient as being 0.01mm above the case (i.e, ignoring natural convection) and some define their specifications using forced cooling with fans. More common is to produce the derating graph using calculated values without proving the figures in a climate controlled oven. However, despite what the derating graphs show or fail to show, a key specification is the efficiency – if two converters are offered in the same case style and construction and one has a higher efficiency, then that will almost certainly have the best high temperature performance. Even though most medical applications do not place the kind of extreme environmental demands on DC/DC converters as, say, the automotive industry, the operating temperature limits are still an important indicator of how well a converter has been designed and built.

Small size medical converters with 1W or 2W of power are mostly unregulated devices as the high isolation value and small case size is of more importance than a precise output voltage. Nevertheless, it is often overlooked that most unregulated converters have no built-in short circuit protection. If the converter output is accidentally short circuited, the converters can be destroyed in a matter of seconds because as the converters possess no regulation, there is no feedback loop to shut down or restrict the input current during overload or short circuit conditions. RECOM has found a simple and elegant solution for this problem and offers its entire unregulated converter range also with a /P option which allows the converter to withstand unlimited short circuits on their outputs without being damaged. Circuit designers that have an application with remote sensors or cables that extend outside of their modules are finding these protected low power versions very useful. High power converters are usually short circuit protected as they incorporate internal feedback loops that can be set up to generate a current foldback characteristic under overload or short circuit to protect the converter.

In summary, any DC/DC converter used in medical applications must not only meet the required safety standards but should also be documented and certified by an independent authorised body. The level of technical support that the supplier can offer the customer is equally crucial. The entire package from specification of the most appropriate product, documentation and support-know-how makes far higher demands on the supplier of DC/DC converters for the area of medical technology than for the more traditional areas such as industrial applications or power supply conversion systems.

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Datasheets and information on other RECOM products can be found on our web-site
http://www.recom-international.com

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