DC-DC CONVERTER APPLICATIONS

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terminology

The data sheet specification for DC-DC converters contains a large quantity of information. This terminology is aimed at ensuring the user is interpreting the data provided correctly and obtaining the necessary information for their circuit application.

absolute maximum ratings :

The absolute maximum ratings are the limits to which the devices can be stressed without causing permanent and irreparable damage. These limits are not the normal operating or functional limits of the devices and operating at the absolute maximum ratings will produce different parametric results to those quoted in the data sheet.

input voltage range :

The range of input voltage that the device can tolerate and maintain functional performance.

load voltage regulation :

The change in output voltage over the specified change in output load. Usually specified as a percentage of the nominal output voltage, for example if a 1V change in output voltage is measured on a 12V output device, load voltage regulation is 8.3%. For unregulated devices the load voltage regulation is specified over the load range 10% to 100% of full load.

line voltage regulation :

The change in output voltage for a given change in input voltage, expressed as percentages. For example, assume a 12V input, 5V output device exhibited a 0.5V change at the output for a 1.2V change at the input, line regulation would be 1 %/%.

output voltage accuracy :

The proximity of the output voltage to the specified nominal value. This is given as a tolerance envelope for unregulated devices with the nominal input voltage applied. For example, a 5V specified output device at 100% load may exhibit a measured output voltage of 4.75V, i.e. a voltage accuracy of -5%).

input and output ripple :

The amount of voltage droop at the input or output between switching cycles. The value of voltage ripple is a measure of the storage ability of the filter capacitors.

input to output isolation :

The dielectric breakdown strength test between input and output circuits. This is the isolation voltage the device is capable of withstanding for a specified time, usually 1 second. (NMV series is 1 minute)

insulation resistance :

The resistance between input and output circuits. This is usually measured at 500V DC

efficiency at full load :

The ratio of power delivered from the device to power supplied to the device when the part is operating under 100% load conditions.

temperature drift :

The change in voltage, expressed as a percentage of the nominal, per degree change in ambient temperature. This parameter is related to several other temperature dependent parameters, mainly internal component drift.

temperature above ambient :

The temperature rise developed by the device under full load conditions. This is related to efficiency.

switching frequency :

The nominal frequency of operation of the switching circuit inside the DC-DC converter. The ripple observed on the input and output pins is usually twice the switching frequency due to full wave rectification and the push-pull configuration of the driver circuit.

no load power consumption :

This is a measure of the switching circuits requirement to function, it is determined with zero output load and is a limiting factor for the total efficiency of the device.

isolation capacitance :

The input to output coupling capacitance. This is not actually a capacitor, but the parasitic capacitive coupling between the transformer primary and secondary windings. Isolation capacitance is typically measured at 1MHz to reduce the possibility of the on-board filter capacitors affecting the results.

mean time to failure (MTTF) :

These figures are calculated expected device lifetime figures using the hybrid circuit model of MIL-HDBK-217F. The hybrid model has various accelerating factors for operating environment (π_E), maturity (π_L), screening (π_Q), hybrid function (π_F) and a summation of each individual component characteristic (λ_C). The equation for the hybrid model is then given by;

$$\lambda = \sum (N_C \, \lambda_C)\,(1 + 0.2\pi_E)\,\pi_L\,\pi_F\,\pi_Q$$

(failures in 10^6 hours)

The MTTF figure is the reciprocal of this value.

In the data book all figures for MTTF are given for the ground benign (GB) environment ($\pi_E = 0.5$), this is considered the most appropriate for the majority of applications in which these devices are likely to be designed in. However, this is not the only operating environment these devices can be used for and hence those users wishing to incorporate these devices into a more severe environment can calculate the predicted MTTF from the following data.

The MIL-HDBK-217F has military environments specified, hence some interpretation of these is required to apply them to standard commercial environments. Table 1 gives approximate cross references from MIL-HDBK-217F descriptions to close commercial equivalents. Please note that these are not implied by MIL-HDBK-217F but are our interpretation, also we have reduced the number of environments from 14 to 6 which are most appropriate to commercial

Environment	π_E Symbol	MIL-HDBK-271F Description	Commercial Interpretation or Examples
Ground Benigh	GB	Non-mobile, temperature and humidity controlled environments readily accessible to maintenance	Laboratory equipment, test instruments, desktop PC's, static telecomms
Ground Mobile	GM	Equipment installed in wheeled or tracked vehicles and equipment manually transported	In-vehicle instrumentation, mobile radio and telecomms, portable PC's
Naval Sheltered	NS	Sheltered or below deck equipment on surface ships or submarines	Navigation, radio equipment and instrumentation below deck
Aircraft Inhabited Cargo	AIC	Typical conditions in cargo compartments which can be occupied by aircrew	Pressurised cabin compartments and cock-pit, in flight entertainment and non-safety critical applications
Space Fight	SF	Earth orbital. Vehicle in neither powered flight nor in atmospheric re-entry	Orbital communications satellite, equipment only operated once in-situ
Missile Launch	ML	Severe conditions relating to missile launch	Severe vibrational shock and very high accelerating forces, satellite lauch conditions

Table 1 : *Interpretation of Environmental Factors*

applications. For a more detailed understanding of the environments quoted and the hybrid model it is recommended that a full copy of MIL-HDBK-217F is obtained.

It is interesting to note that space flight and ground benign have the same environment factors. It could be suggested that the act of achieving space flight should be the determining environmental factor (i.e. missile launch).

The hybrid model equation can therefore be rewritten for any given hybrid, at a fixed temperature, so that the environmental factor is the only variable;

$$\lambda = k\,(1 + 0.2\pi_E)$$

The MTTF values for other environment factors can therefore be calculated from the ground benign figure quoted at each temperature point in the data book. Hence predicted MTTF figures for other environments can be calculated very quickly. All the values will in general be lower and since the majority of the mobile environments have the same factor a quick divisor can be calculated for each condition. Therefore the only calculation necessary is to divide the quoted MTTF figure by the divisor given in table 2.

Environment	π_E Symbol	π_E Value	Divisor
Ground Benign	GB	0.5	1.00
Ground Mobile	GM	4.0	1.64
Naval Sheltered	NS	4.0	1.64
Aircraft Inhabited Cargo	AIC	4.0	1.64
Space Flight	SF	0.5	1.00
Missile Launch	ML	12.0	3.09

Table 2 : *Environment Factors*

noise :

Input conducted noise is given in the line conducted spectra for each DC-DC converter (see EMC issues for further details). Noise is affected significantly by pcb layout, measurement system configuration, terminating impedance etc. and is difficult to quote reliably and with any accuracy other than via a spectrum analysis type plot. There will be some switching noise present on top of the ripple, however, most of this is easily reduced by use of small capacitors or filter inductors as shown in the application notes.

temperature derating curve :

The component will operate over a wider temperature range if less power is drawn from the output and the device is already running. The temperature derating curve shows the operating power-temperature range once the converter is started.

There are almost limitless applications for DC-DC converters since these components provide the basic power supply function on many circuit boards. These application notes will concentrate on using the converters in some specific applications as well as highlighting good design practice for the circuit around the DC-DC converter. Where detailed designs are given, they are for illustrative purposes to demonstrate a principle, even though the circuit has been built to solve a particular circuit or design problem.

isolation

One of the main features of the majority of Newport Components DC-DC converters is their high galvanic isolation capability. This allows several variations on circuit topography by using a single DC-DC converter.

The basic input to output isolation can be used to provide either a simple isolated output power source, or to generate different voltage rails and/or dual polarity rails (see figure 1).

These configurations are most often found in instrumentation, data processing and other noise sensitive circuits where it is necessary to isolate the load and noise presented to the local power supply rails from that of the entire system. Usually local supply noise appears as common mode noise at the converter and does not pollute the main system power supply rails.

The isolated positive output can be connected to the input ground rail to generate a negative supply rail if required. Since the output is isolated from the input the choice of

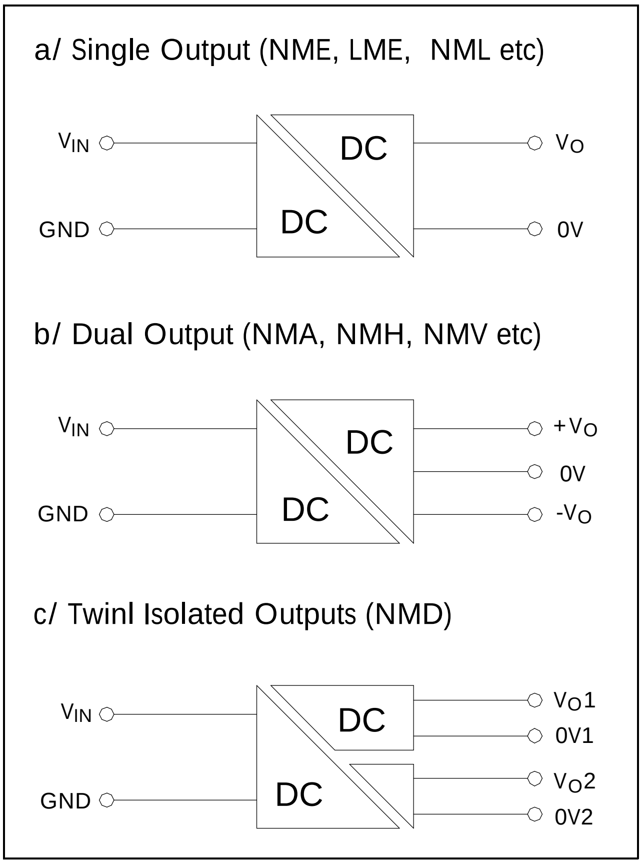


Figure 1 : *Standard Isolated Configurations*

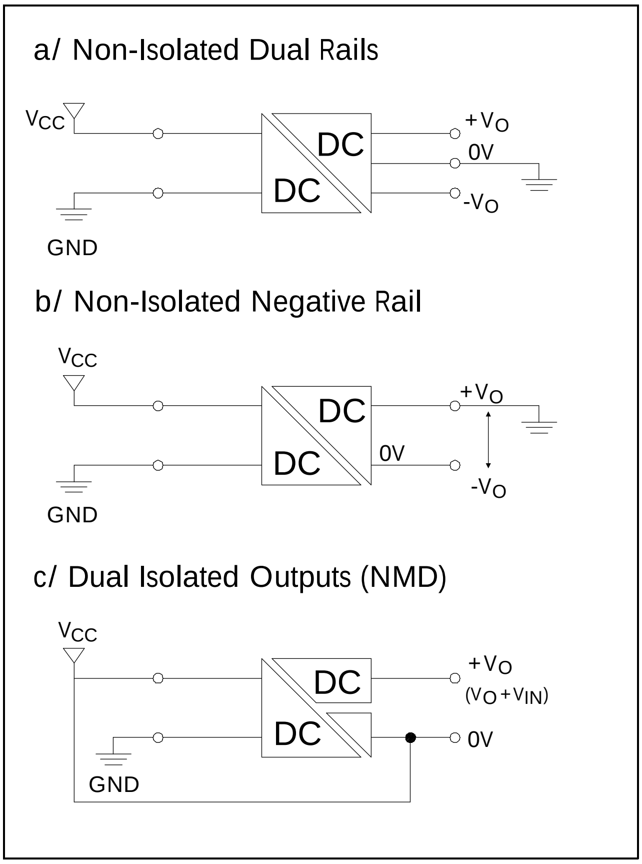


Figure 2 : *Alternative Supply Configurations*

reference for the output side can be relatively arbitrary, for example an additional single rail can be generated above the main supply rail or offset by some other DC value (see figure 2).

Regulated converters need more consideration than the unregulated types for mixing the reference level. Essentially the single supply rail has a regulator in its $+V_O$ rail only, hence referencing the isolated ground will only work if all the current return is through the DC-DC and not via other external components (e.g. diode bias, resistor feed). Having an alternative return path can upset the regulation and the performance of the system may not equal that of the converter.

connecting DC-DC converters in series

Galvanic isolation of the output allows multiple converters to be connected in series simply by connecting the positive output of one converter to the negative of another (see figure 3). In this way non-standard voltage rails can be generated, however, the current output of the highest output voltage converter should not be exceeded.

When converters are connected in series, additional filtering is strongly recommended as the converters switching circuits are not synchronised. As well as a summation of the ripple voltages, the output could also

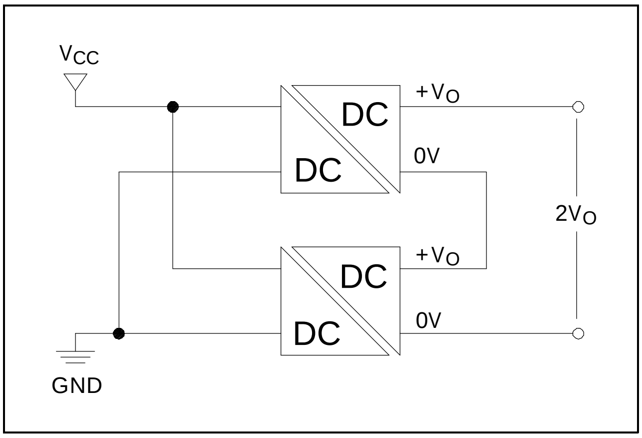


Figure 3 : *Connecting DC-DC Converters in Series*

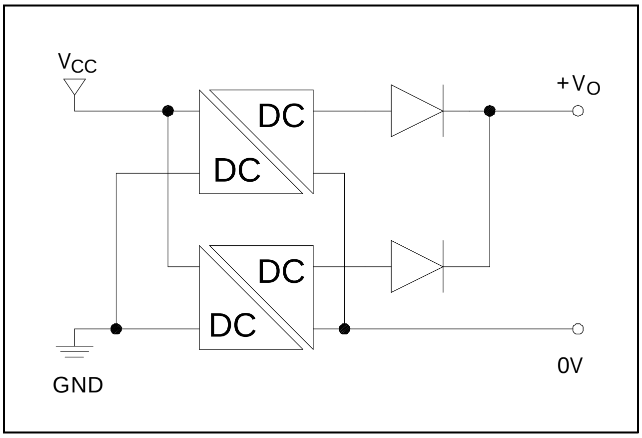


Figure 4 : *Diode Coupled Paralleled DC-DC Converters*

produce relatively large beat frequencies. A capacitor across the output will help, as will a series inductor (see filtering).

connecting DC-DC converters in parallel

If the available power output from a single converter is inadequate for the application then multiple converters can be paralleled to produce a higher output power.

It should be noted that it is always preferable to parallel multiple converters of the same type. For example if a 2.5W converter is required, then either 2 NMHs should be used or 3 NMAs, not an NMH and NMA. The reason for this is that the output voltages are not sufficiently well matched to guarantee that an NMH would supply twice as much as an NMA and the situation could occur where there was only 1W being drawn from the NMH and 1.5W from the NMA. Even with parallel converters of the same type, loading will be uneven, however, there is only likely to be around a 10% difference in output load when the output voltages are well matched.

When connecting converter outputs it should be remembered that the switching will not be synchronous, hence some form of coupling should be employed. One possible solution is to use a diode feed, this is suitable mainly for 12V and 15V output types only where the diode voltage drop (typically 0.6V) will not significantly affect the circuit functionality (see figure 4). With 5V and 9V supplies the diode drop is generally too large to consider as a suitable means of connecting paralleled converters.

This method also has a beat frequency that will superimpose itself over the ripple of the two converters, this can be reduced by using an external capacitor at the paralleled output.

The preferred method of connecting converters in parallel is via series inductors on the output (see figure 5). This configuration not only has a lower loss of voltage than the diode method, but by suitable choice of inductor and an additional external capacitor, the beat frequency can be significantly reduced, as will the ripple from each converter. Suitable values are given in table 3, these typically reduce the beat and ripple frequencies by a factor of 10.

Product Range	Output Voltage	Inductance (μH)
LME NMA NMD NME NMH NML NMV	3.3	33
	5	47
	9	100
	12	220
	15	330

Table 3 : *Parallel Output Inductors*

recommended values for paralleled DC-DC Converters

The capacitance value used (C_{OUT}) should be approximately 1μF per parallel channel (i.e. for 2 parallel single output converters, 2μF between the common positive output and 0V).

The same comments can be applied to the input circuit for converters whose inputs are paralleled and similar values for inductance and input capacitance should be used as shown above.

In general paralleling converters should only be done when essential and a higher power single converter is always a preferable solution. There should always be a correction factor of the maximum power rating to allow for mismatch between converters and a select at full load test is recommended to ensure the output voltage is matched to within 1% or 2%. In general a factor of 0.9 should be used to provide a power safety margin per converter (e.g. 2 NMH converters paralleled should only be used up to a power level of 3.6W, not their 4W maximum). At most three DC-DC converters can be paralleled with a high level of confidence in the overall performance. If the circuit needs more power than three converters in parallel, then a single converter with a much higher power rating should be considered.

Regulated output DC-DC converters should not be paralleled since their output voltage would need to be very accurately matched to ensure even loading (to within the tolerance of the internal linear regulator). Paralleling regulated converters could cause one of the parts to be overloaded. If a high power regulated supply is required, it would be better to parallel unregulated converters and add an external linear regulator.

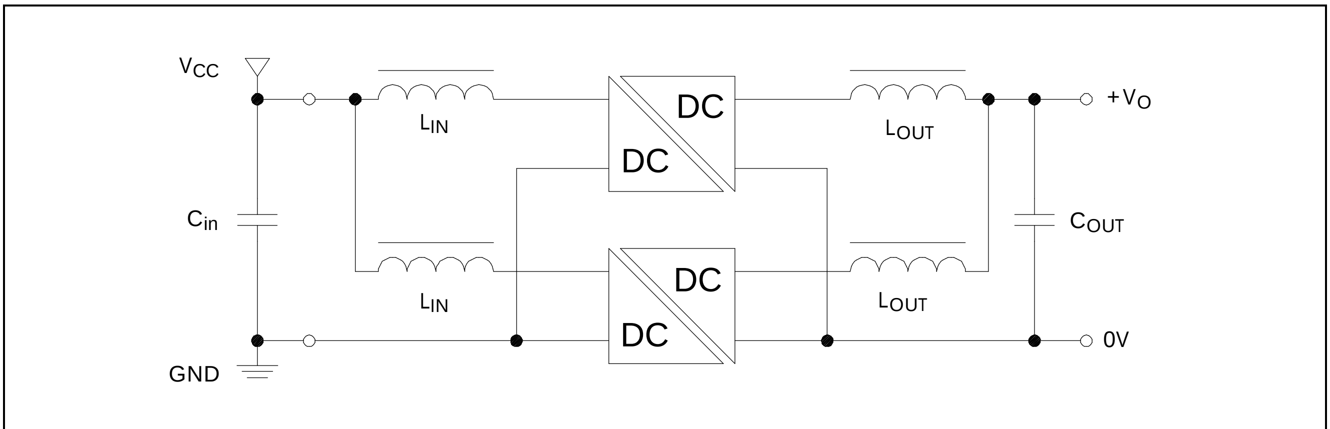


Figure 5 : *Fully Filtered Paralleled DC-DC Converters*

filtering

All Newport Components isolated DC-DC converters have a fixed characteristic frequency at which the device operates. This fixed frequency allows filtering that is relatively simple compared to pulse-skipping types. In a pulse skipping converter a large range of frequencies are encountered as the device adjusts the pulse interval for loading conditions.

When reducing the ripple from the converter, at either the input or the output, there are several aspects to be considered. Newport Components recommend filtering using simple passive LC networks at both input and output (see figure 6). A passive RC network could be used, however, the power loss through a resistor is considered too high. The self resonant frequency of the inductor needs to be significantly higher than the characteristic frequency of the DC-DC (typically 100kHz for Newport Components DC-DC converters). The DC current rating of the inductor also needs consideration, a rating of approximately twice the supply current is recommended.

The DC resistance of the inductor is the final consideration that will give an indication of the DC power loss to be expected from the inductor.

The value of inductor and capacitor to use is given in the table below for the majority of Newport Components DC-DC converters. The capacitance is chosen to form a pi filter to match the input or output capacitor of the DC-DC converter. The inductor is chosen to cause heavy attenuation of the characteristic frequency when combined with the given capacitors.

recommended values for filtered DC-DC converters

Those converters that feature an internal linear regulator (eg NMF, NMXSO) do not require external filtering at the output but can benefit from the above filter combinations at the input (see table 4).

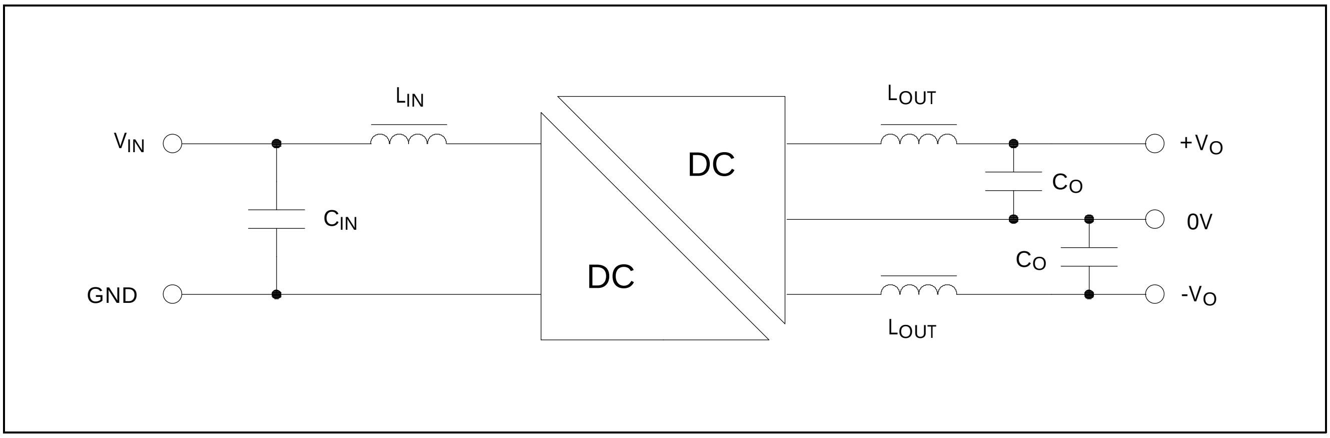


Figure 6 : *Input and Output Filtering*

Product Range	Input Voltage	Inductance/ Capacitance	Output Voltage	Inductance/ Capacitance
LME NMA NME NMH NMD NMV	3.3	33μH / 1.5μF	3.3	33μH / 1.5μF
	5	47μH / 1.0μF	5	47μH / 1.0μF
	12	220μH / 1.0μF	9	100μH / 1.0μF
	24	470μH / 470nF	12	220μH / 1.0μF
	48	680μH / 180nF	15	330μH / 1.0μF

Table 4 : *Recommended Values for Filtered DC-DC's*

limiting inrush current

Using a series inductor at the input will limit the current that can be seen at switch on (see figure 7). If we consider the circuit without the series inductor, then the input current is given by ;

$$i = \frac{V}{R}\exp\left(\frac{-t}{RC}\right)$$

When the component is initially switched on (i.e. t=0) this simplifies to ;

$$i = \frac{V}{R}$$

This would imply that for a 5V input, with say 50mΩ track and wire resistance, the inrush current could be as large as 100A, this could cause a problem for the DC-DC converter.

A series input inductor therefore not only filters the noise from the internal switching circuit, but also limits the inrush current at switch on.

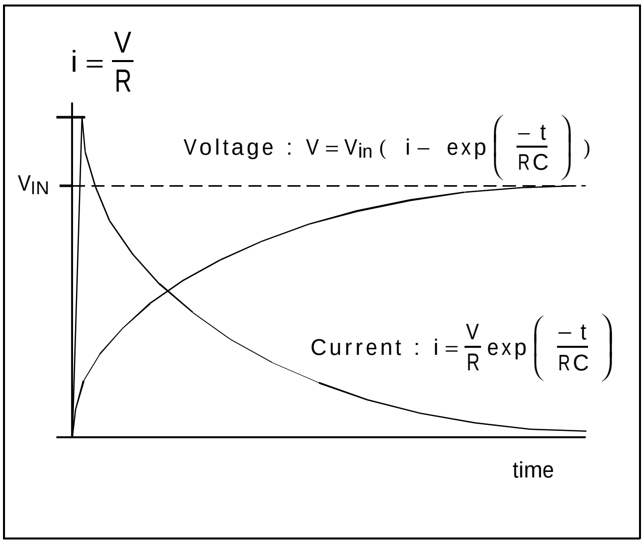


Figure 7 : *Input Current & Voltage at Switch On*

maximum output capacitance

A simple method of reducing the output ripple is simply to add a large external capacitor. This can be a low cost alternative to the LC filter approach, although not as effective. There is also the possibility of causing start up problems if the output capacitance is too large.

With a large output capacitance, at switch on there is no charge on the capacitors and the DC-DC converter immediately experiences a large current demand at its output. The inrush current can be so large as to exceed the ability of the DC-DC converter and the device can go into an undefined mode of operation. In the worst case scenario the device can give a lower than expected DC output with a very high ripple. The DC-DC converter may survive this condition, however, the circuit being supplied is unlikely to function under this supply scheme.

Newport Components recommend a maximum safe operating value of 10μF for the output per channel. When used in conjunction with a series output inductor this value can be raised to 47μF should extremely low ripple be required.

settling time

The main reason for not fitting a series inductor internally is that many applications require a fast power on time (there is also a size constraint with our miniature parts). When the power on voltage is a controlled fast ramp, then the output can respond within 500μs of the input reaching its target voltage (measured on a range of NMA and NMH components under full output load without external filters). The use of external filters and additional input or output capacitance will slow this reaction time. It is therefore left to the designer to decide on the predominant factors affecting their circuit; settling time or noise performance.

isolation capcitance and leakage current

The isolation barrier within the DC-DC converter has a capacitance which is a measure of the coupling between input and output circuits. Providing this is the largest coupling source, a calculation of the leakage current between input and output circuits can be estimated.

Assuming we have a known isolation capacitance (C_{IS} - refer to DC-DC converter data) and a known frequency for either the noise or test signal, then the expected leakage current (I_L) between input and output circuits can be calculated from the impedance.

The general isolation impedance equation for a given frequency (f) is given by ;

$$Z_f = \frac{1}{j\,2\pi\ f\,C_{is}}$$

For an NMA0505S, the isolation capacitance is 18pF, hence the isolation impedance to a 50Hz test signal is ;

$$Z_{50} = \frac{1}{j\,2\pi\ \ 50\ \ 18pF} = 177M\,\Omega$$

If using a test voltage of 1kVrms, the leakage current is ;

$$i_L = \frac{V_{test}}{Z_f} = \frac{1000V}{177M\,\Omega} = \ 5.65\,\mu A$$

It can be easily observed from these simple equations that the higher the test or noise voltage, the larger the leakage current, also the lower the isolation capacitance the lower the leakage current. Hence for low leakage current, high noise immunity designs, high isolation DC-DC converters should be selected with an appropriate low isolation capacitance.

overload protection

Although the use of filtering will prevent excessive current at power-on, under normal operating conditions, there is no protection against an output circuit taking excessive power or even going short-circuit. When this happens the DC-DC converter will take a large input current to try to supply the output, eventually the converter will overheat and destroy itself if this condition is not rectified (short circuit overload is only guaranteed for 1s on an unregulated part).

There are several ways to prevent overload at the outputs destroying the DC-DC converter, the simplest being a straight forward fuse, sufficient tolerance for inrush current is required to ensure the fuse does not blow on power-on (see figure 8). Another simple scheme that can be applied is a circuit breaker.

There is also the potential to add some intelligence to the overload scheme by either detecting the input current, or the output voltage (see figure 9). The simplest implementation for overload protection at the input is to have the device supplied via a linear regulator with an internal thermal shutdown facility. This does however reduce the overall efficiency significantly.

If there is an intelligent power management system at the input, using a series resistor (in place of the series inductor) and detecting the voltage drop across the device to signal the management system can be used. A similar scheme can be used at the output to determine the output voltage, however, if the management system is on the input side, the signal will need to be isolated from the controller to preserve the system isolation barrier (see figure 10).

The thermal dissipation in a series resistor on the output can also be used to determine overloading and preserve the isolation barrier. If a thermistor or other thermally sensitive device is mounted close to the resistor this can be used to indicate an overload condition. System temperature will also need to be known to provide a suitable offset for different operating environments.

There are several other current limiting techniques that can be used to detect an overload situation, the suitability of these is left to the designer. The most important thing to consider is how this information will be used. If the system needs to signal to a controller the location or module causing the overload some form of intelligence will be needed. If the device simply needs to switch off, a

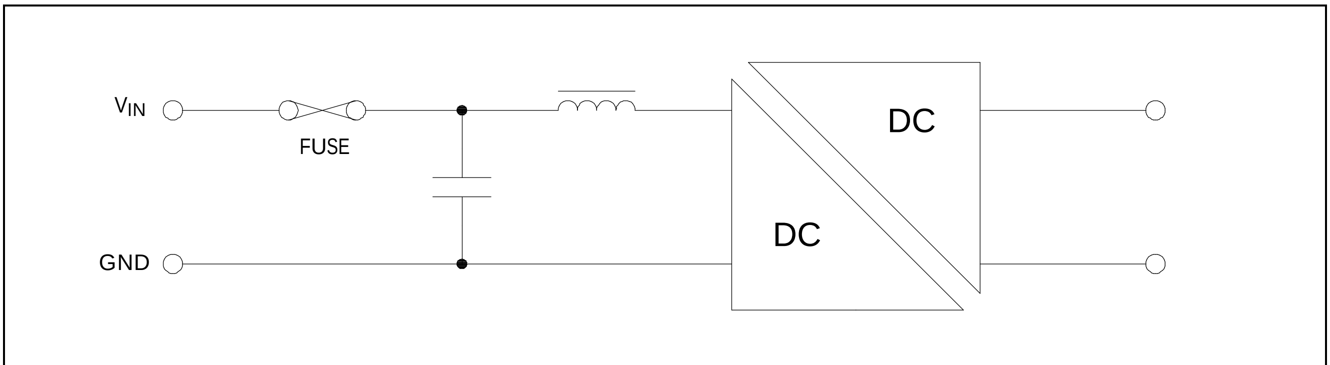
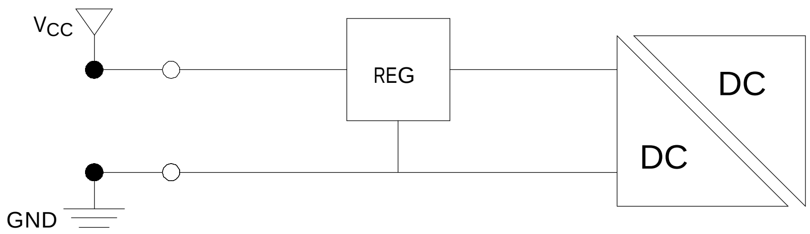
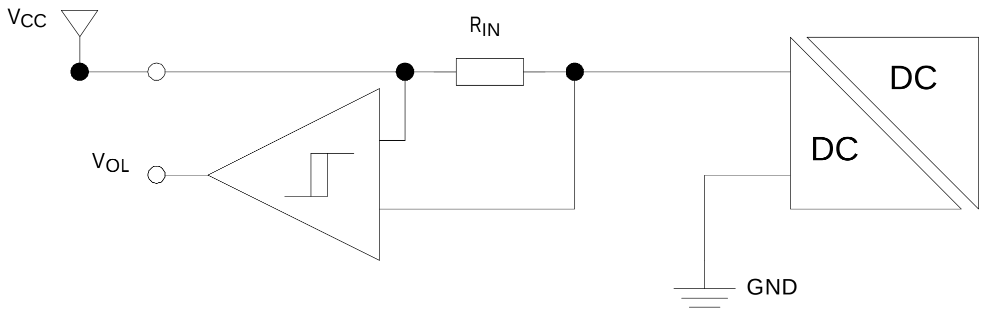


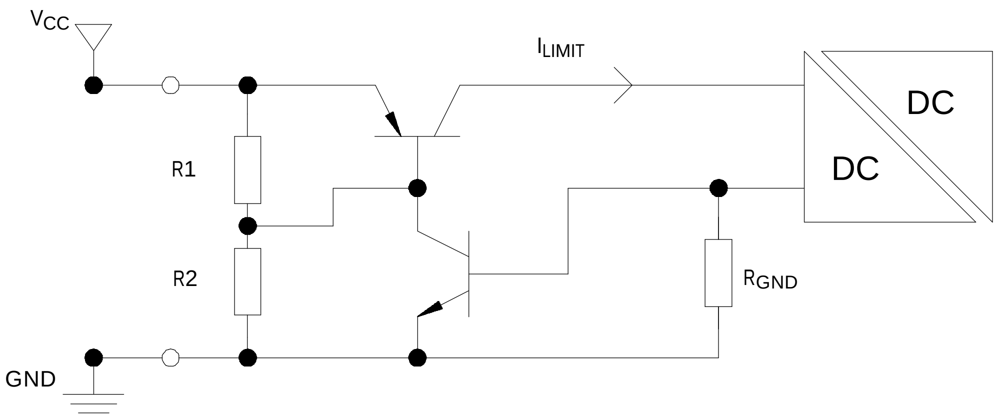
Figure 8 : *Simple Overload Protection*



a/ Linear Regulator with Internal Thermal Shutdown



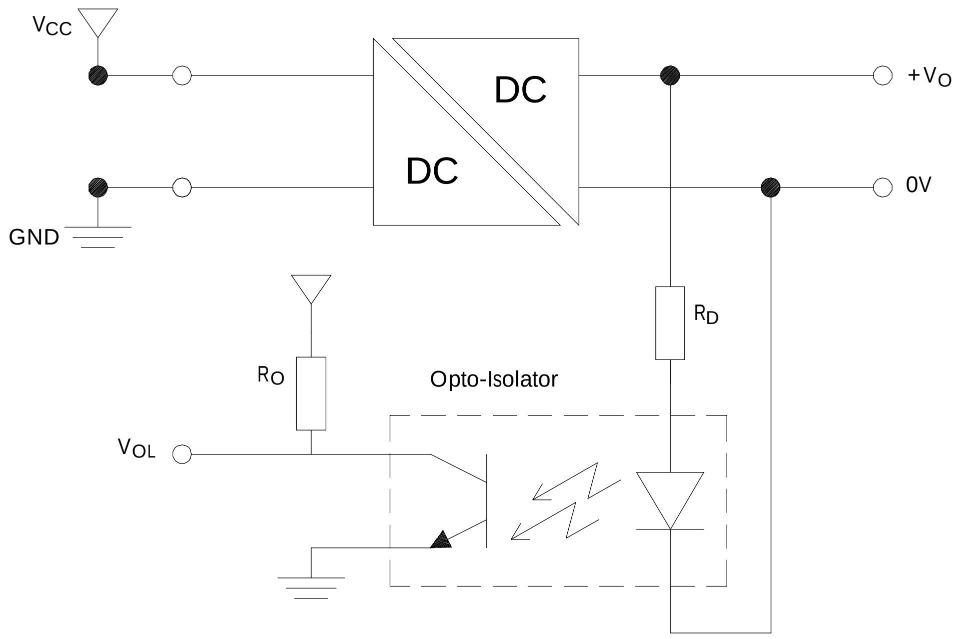
b/ Series Resistor for Input Current Measurement



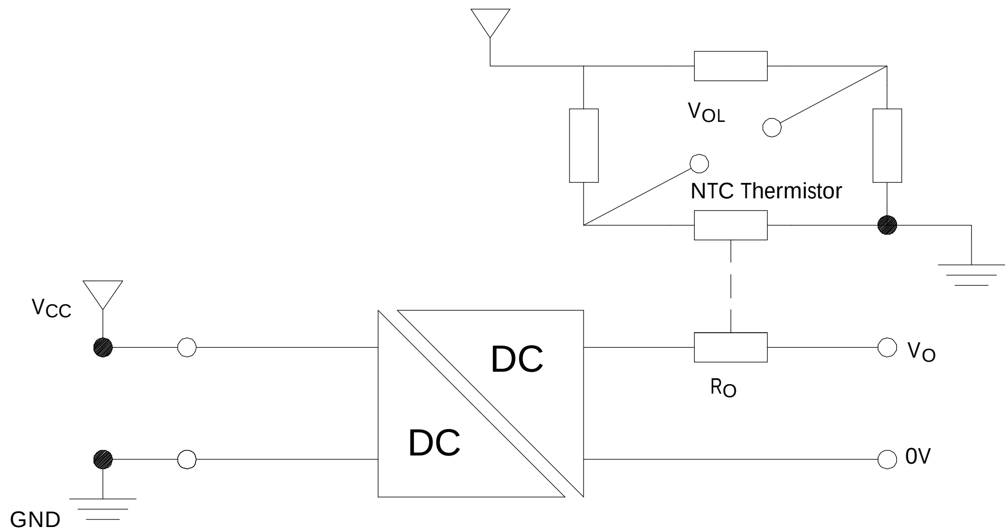
c/ Ground Current Monitor

Choose current limit (ILIMIT) and ground resistor (RGND) so that : 0.7V = RGND x ILIMIT.

Figure 9 : *Input Monitored Overload Protection*



a/ Opto-Isolated Overload Detector
On overload +VO falls and the LED switches off, the VOL. line is then pulled high.



b/ Thermal Overload Detector

Figure 10 : *Ouput Monitored Overload Protection*

simple fuse type arrangement will be adequate.

All Newport Components DC-DC converters which include an internal linear regulator have a thermal overload shut-down condition which protects these devices from excessive overload. If this condition is to be used to inform a power management system the most suitable arrangement is the output voltage detector (see figure 10a), since this will fall to near zero on shut-down. A thermal probe on the case of the DC-DC converter is also a possible solution.

input voltage drop-out (brown-outs)

When the input voltage drops, or is momentarily removed, the output circuit would suffer similar voltage drops. For short period input voltage drops, such as when other connected circuits have an instantaneous current demand, or devices are plugged in or removed from the supply rail while 'hot', a simple diode-capacitor arrangement can prevent the output circuit from being effected.

The circuit uses a diode feed to a large reservoir capacitor (typically 47uF electrolytic) which provides a short term reserve current source for the converter, the diode blocking other circuits from draining the capacitor over the supply rail. When combined with an in line inductor this can also be used to give very good filtering. The diode volt drop needs to be considered in the power supply line under normal supply conditions, a low drop Schottky diode is recommended (see figure 11).

no load over voltage lock-out

Unregulated DC-DC converters are expected to be under a minimum of 10% load, hence below this load level the output voltage is undefined. In certain circuits this could be a potential problem.

The easiest way to ensure the output voltage remains within a specified tolerance is to add external resistors so that there is always a 10% loading on the device (see figure 12). This is rather inefficient in that 10% of the power is always being taken by this load, hence only 90% is available to the additional circuitry.

Zener diodes on the output are another simple method. It is recommended that

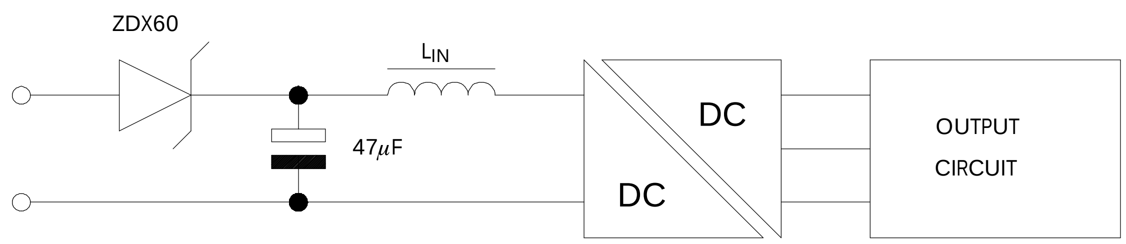


Figure 11 : *Input Voltage Drop-out*

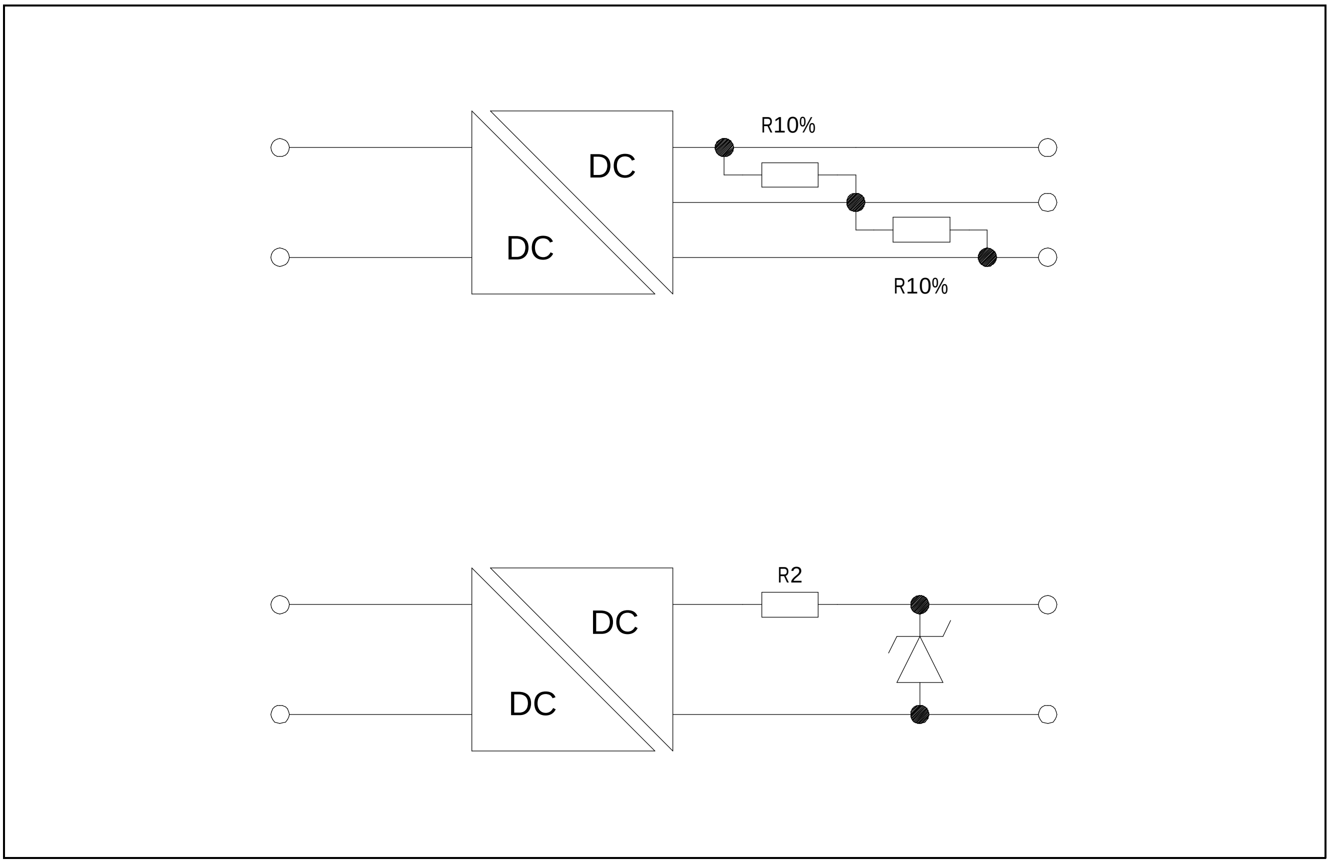


Figure 12 : *No Load Over Voltage Lock-out*

these be used with a series resistor or inductor as when the Zener action occurs a large current surge may induce signal noise into the system.

long distance supply lines

When the supply is transmitted over a cable there are several reasons why using an isolated DC-DC converter is good design practice (see figure 13). The noise pick up and EMC susceptibility of a cable is high

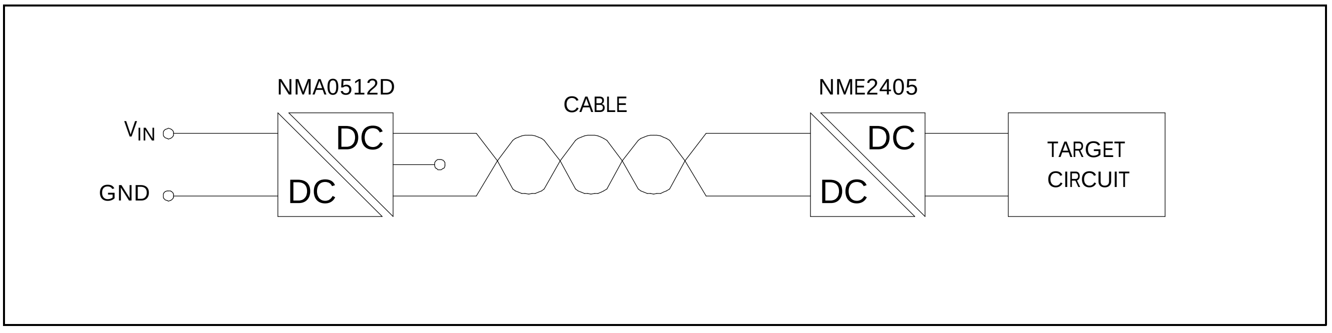


Figure 13 : *Long Distance Power Transfer*

compared to a pcb track, by isolating the cable via a DC-DC converter at either end, any cable pick-up will appear as common mode noise and should be self cancelling at the converters.

Another reason is to reduce the cable loss by using a high voltage, low current power transfer through the cable and re-converting at the terminating circuit. This will also reduce noise and EMC susceptibility since the noise voltage required to affect the rail is also raised.

For example, compare a system having a 5V supply and requiring a 5V, 500mW output at a remote circuit. Assume the connecting cable has a 100Ω resistance. Using an NME0505D to convert the power at either end of the cable, with a 100mA current the cable will lose 1W (I^2R) of power, the NME would not be suitable since this is its total power delivery, hence there is no power available for the terminating circuit. Using an NMA0512D to generate 24V and an NME2405D to regenerate 5V, only a 21mA supply is required through the cable, a cable loss of 44mW.

LCD display bias

An LCD display typically requires a positive or negative 24V supply to bias the crystal. The NME0524 (custom) converter was designed specifically for this application. Having an isolated 0V output this device can be configured as a +24V supply by connecting this to the GND input or a -24V supply by connecting the $+V_O$ output to GND (see figure 14).

EIA-232 interface

In a mains powered PC often several supply rails are available to power an RS232 interface. However, battery operated PC'S or remote equipment having an RS232 interface added later, or as an option, may not have the supply rails to power an RS232 interface. Using an NMA0512 is a simple single chip solution, allowing a fully EIA-232 compatible interface to be implemented from a single 5V supply rail and only 2 additional components (see figure 15).

3V/5V logic mixed supply rails

There has been a lot of attention given to new I.C.'s and logic functions operating at what is rapidly emerging as the standard supply level for notebook and palmtop computers. The 3.3V supply is also gaining rapid acceptance as the defacto standard for personal telecommunications, however, not all circuit functions required are currently available in a 3.3V powered IC. The system designer therefore has previously had only two options available; use standard 5V logic or wait until the required parts are available in a 3V form, neither being entirely satisfactory and the latter possibly resulting in lost market share.

There is now another option, mixed logic functions running from separate supply rails. A single 3.3V line can be combined with a range of DC-DC converters from Newport Components to generate voltage levels to run virtually any standard logic or interface IC. The Newport Components range includes dual output parts for powering analogue bipolar and amplifier functions (NMA series) as well a single output function for

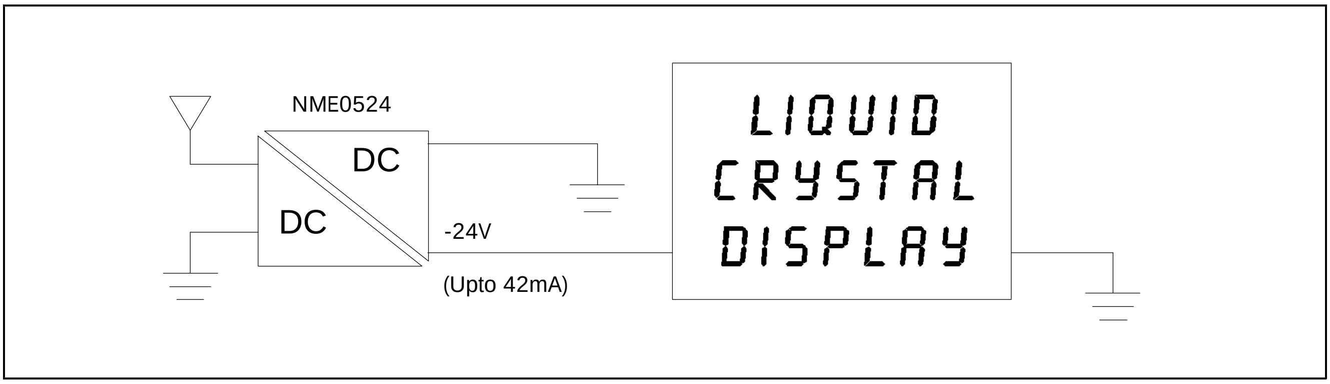


Figure 14 : *LCD Display Bias*

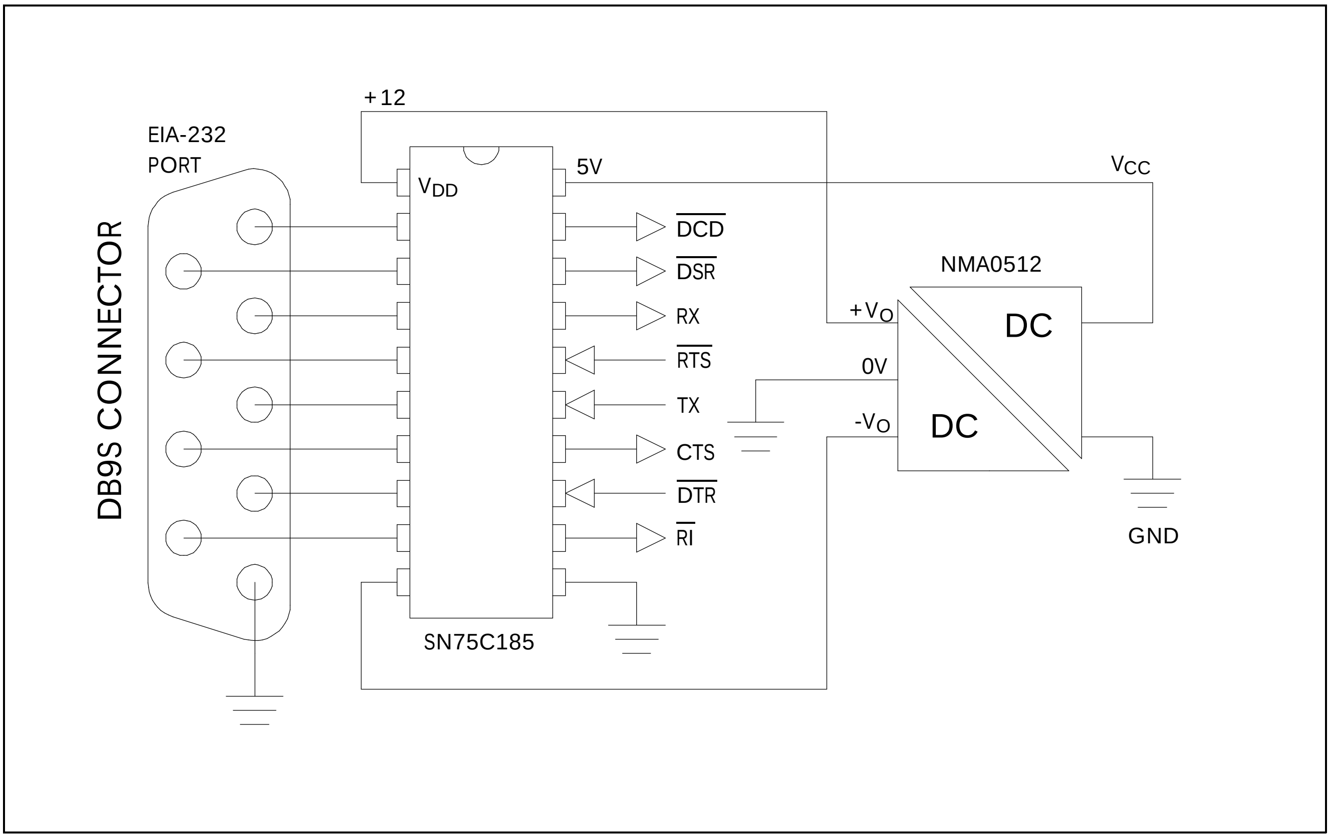


Figure 15 : *Optimised RS232 Interface*

localised logic functions (LME, NME series). A typical example might be an RS232 interface circuit in a laptop PC using a 3.3V interface chip (such as the LT1330) which accepts 3.3V logic signals but requires a 5V supply (see figure 16).

Newport Components has another variation on this theme and has developed two 5V to 3.3V step down DC-DC converters (LME0503 and NME0503). These have been designed to allow existing systems to start incorporating available 3.3V I.C.'s without having to redesign their power supply.

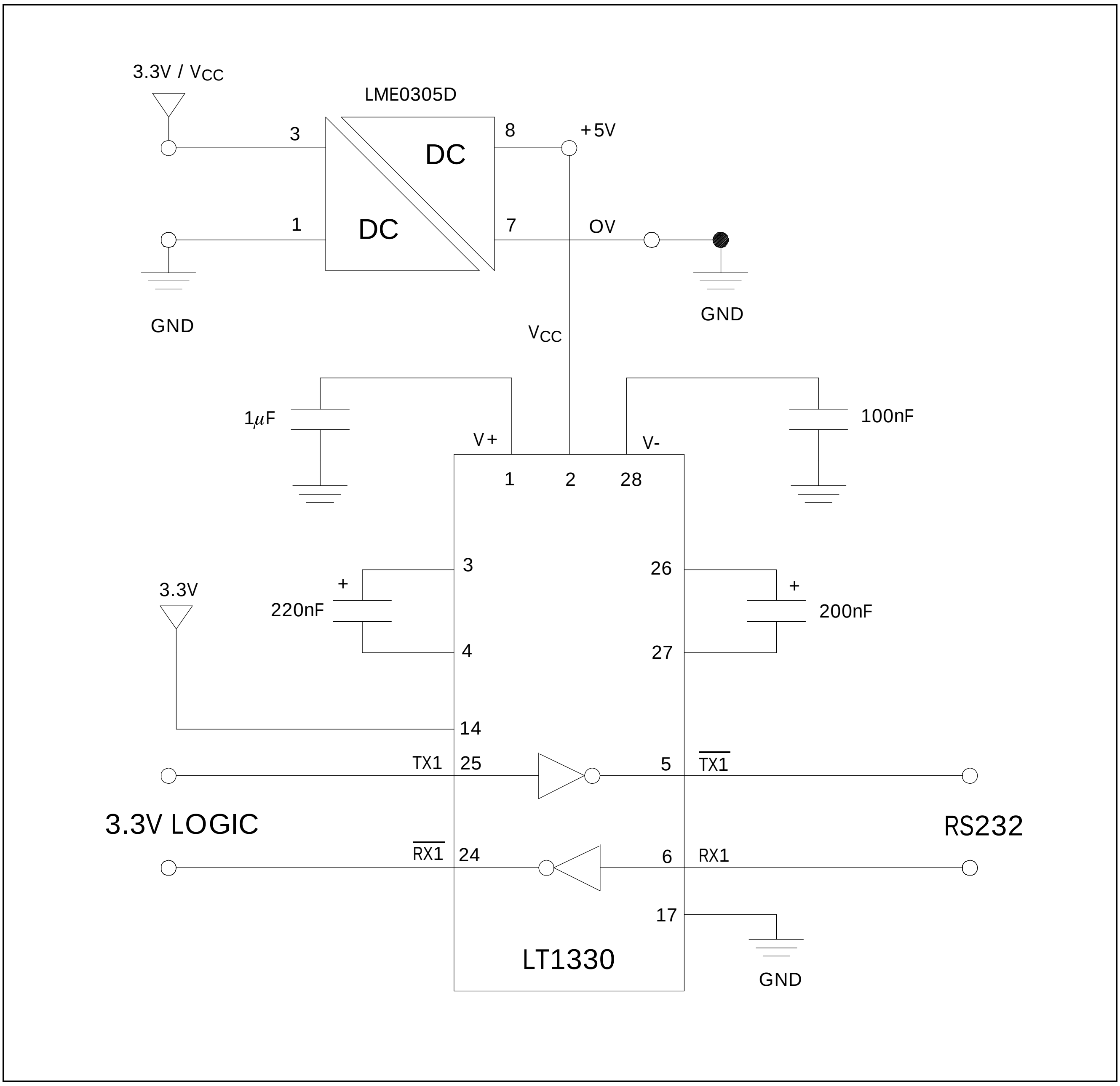


Figure 16 : *RS232 Interface with 3V Logic*

This is particularly important when trying to reduce the overall power demand of a system, but not having available all of the functions at the 3.3V supply.

The main application for this range of devices are system designers who want to provide some functionality that requires a higher voltage than is available from the supply rail, or for a single localised function. Using a fully isolated supply is particularly useful in interface functions and systems maintaining separate analogue and digital ground lines.

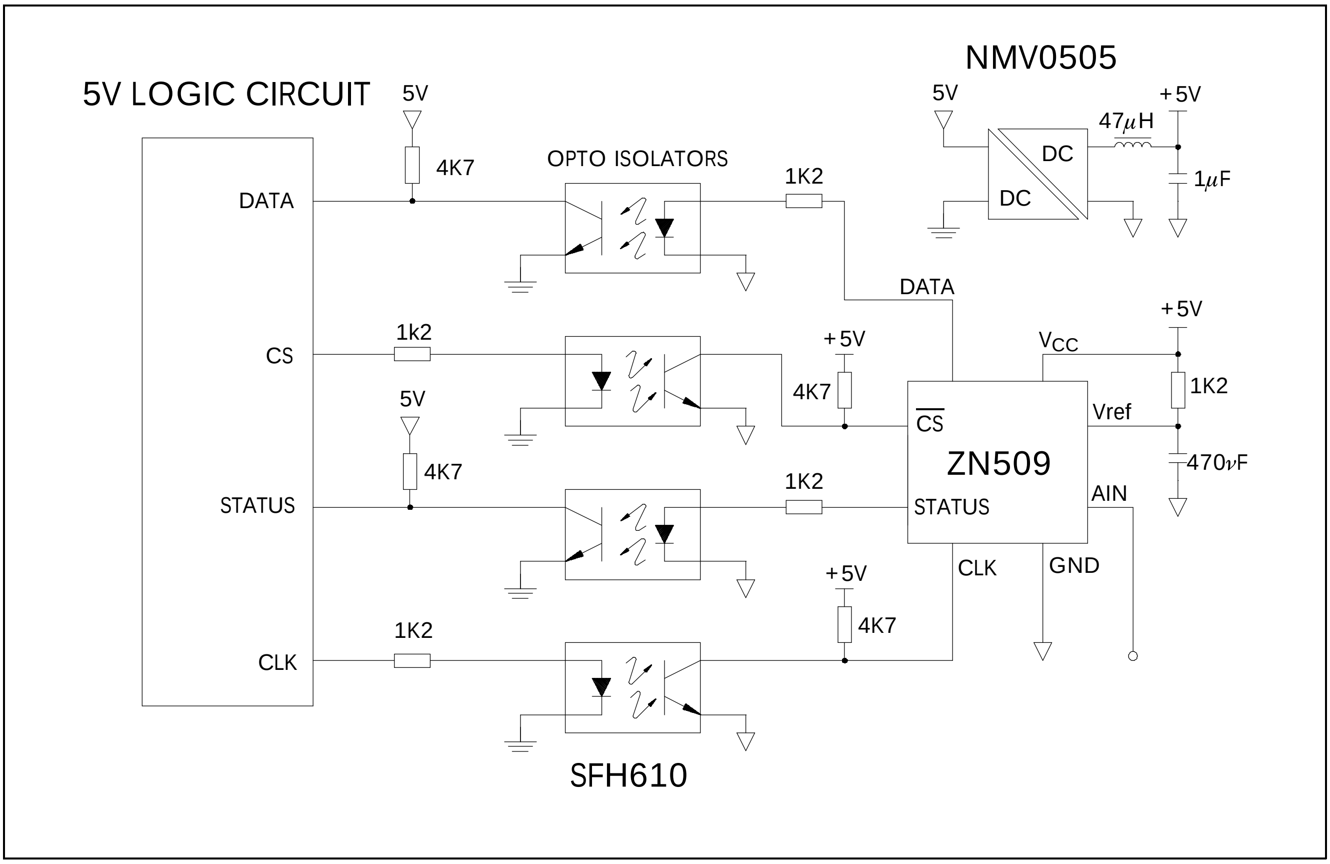


Figure 17 : *Isolated Serial ADC System*

isolated data acquisition system

Any active system requiring isolation will need a DC-DC converter to provide the power transfer for the isolated circuit. In a data acquisition circuit there is also the need for low noise on the supply line, hence good filtering is required.

The circuit shown (see figure 17) provides a very high isolation barrier by using an NMV converter to provide the power isolation and SFH610 opto-isolators for the data isolation. An overall system isolation of 2.5kV is achieved.

EMC considerations

When used for isolating a local power supply and incorporating the appropriate filter circuits as illustrated above, DC-DC converters can present simple elegant solutions to many EMC power supply problems. The range of fixed frequency DC-DC converters is particularly suitable for use in EMC problem situations as the stable, fixed switching frequency gives easily characterised and easily filtered output.

The following notes give suggestions to avoiding common EMC problems in power supply circuits. A more extensive discussion on other aspects of EMC is available in the Newport Components EMC Design Guidelines book.

power supply considerations

- ❒ eliminate loops in supply lines (see figure 18).
- ❒ decouple supply lines at local boundaries (use RCL filters with low Q, see figure 19).
- ❒ place high speed sections close to the power line input, slowest section furthest away (reduces power plane transients, see figure 20).
- ❒ isolate individual systems where possible (especially analogue and digital systems) on both power supply and signal lines (see figure 21).

An isolated DC-DC converter can provide a significant benefit to reducing susceptibility and conducted emission due to isolating both power rail and ground from the system supply. The range of DC-DC converters available from Newport Components all utilise toroidal power transformers and as such have negligible EMI radiation (they also incorporate the recommended pcb layout suggestions as stated in Newport Components EMC Guidelines Data book).

Isolated DC-DC converters are switching devices and as such have a characteristic switching frequency which may need some additional filtering. Some commercial converters offer a pulse skipping technique, which although offering a flat efficiency response gives a very wide spectral range of noise, since it does not have a fixed characteristic frequency. Newport Components devices feature a fixed frequency converter stage which is stable across its full loading and temperature curve, hence it is very easy to filter the switching noise using a single series inductor.

interpretation of DC-DC converter EMC data

Electromagnetic compatibility (EMC) of electrical and electronic products is a measure of electrical pollution. Throughout the world there are increasing statutory and regulatory requirements to demonstrate the EMC of end products. In Europe the EC directive 89/336/EEC requires that any product sold after 1 January 1996 complies with a series of EMC limits, otherwise the product will be prohibited from sale within the EEC and the seller could be prosecuted and fined.

Although DC-DC converters are generally exempt from EMC regulations on the grounds that these are component items, it is the belief of Newport Components Ltd. that the information on the EMC of these components can help designers ensure their end product can meet the relevant statutory EMC requirements. It must be remembered however, that the DC-DC converter is unlikely to be the last component in the chain to the mains supply, hence the information quoted needs interpretation by the circuit designer to determine its impact on the final EMC of their system.

The notes given here are aimed at helping the designer interpret the effect the DC-DC converter will have on the EMC of their end product by describing the methods and rationale for the measurements made. Where possible CISPR and EN standards have been used to determine the noise spectra of the components, however, all of the standards reference mains powered equipment and interpretation of these specifications is necessary to examine DC supplied devices.

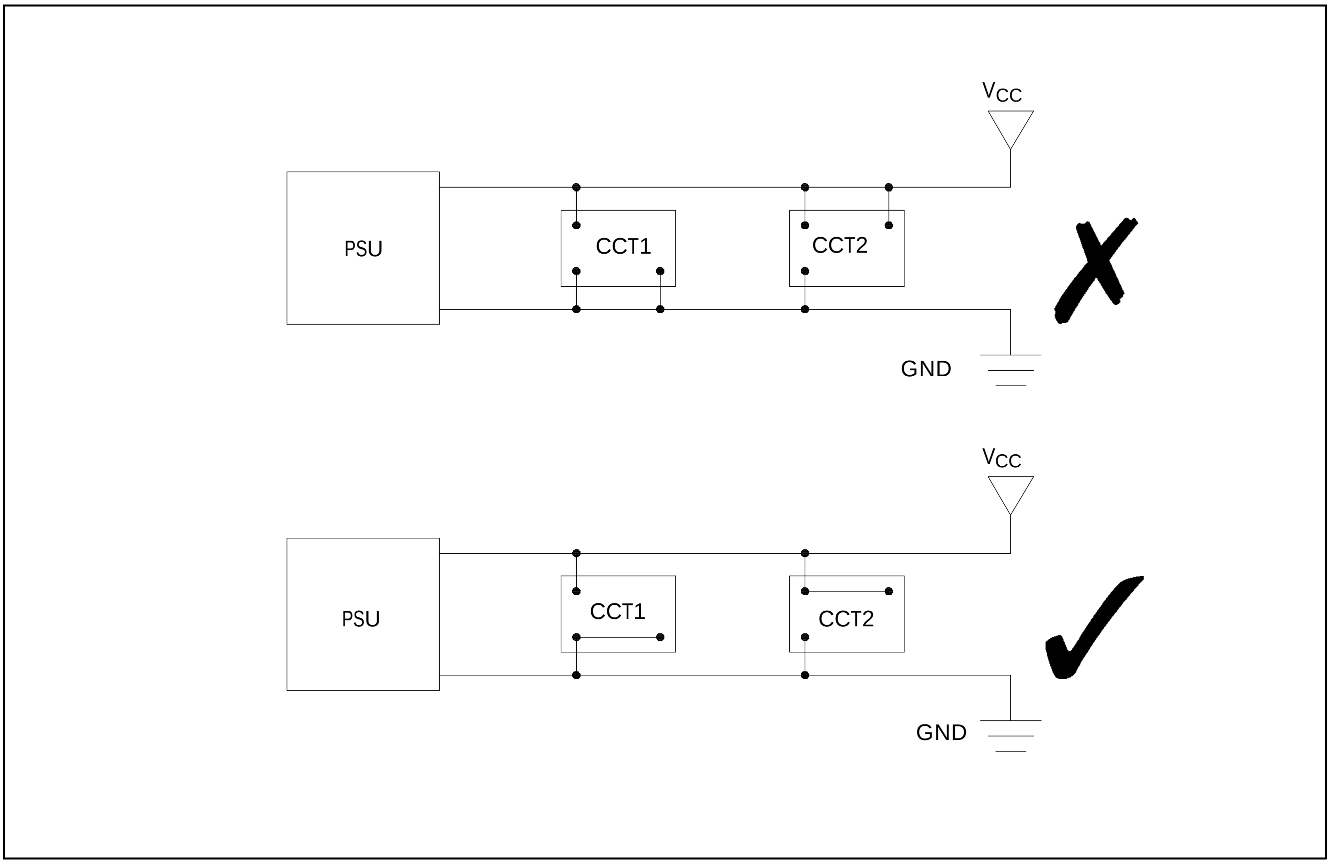


Figure 18 : *Eliminate Loops in Supply Line*

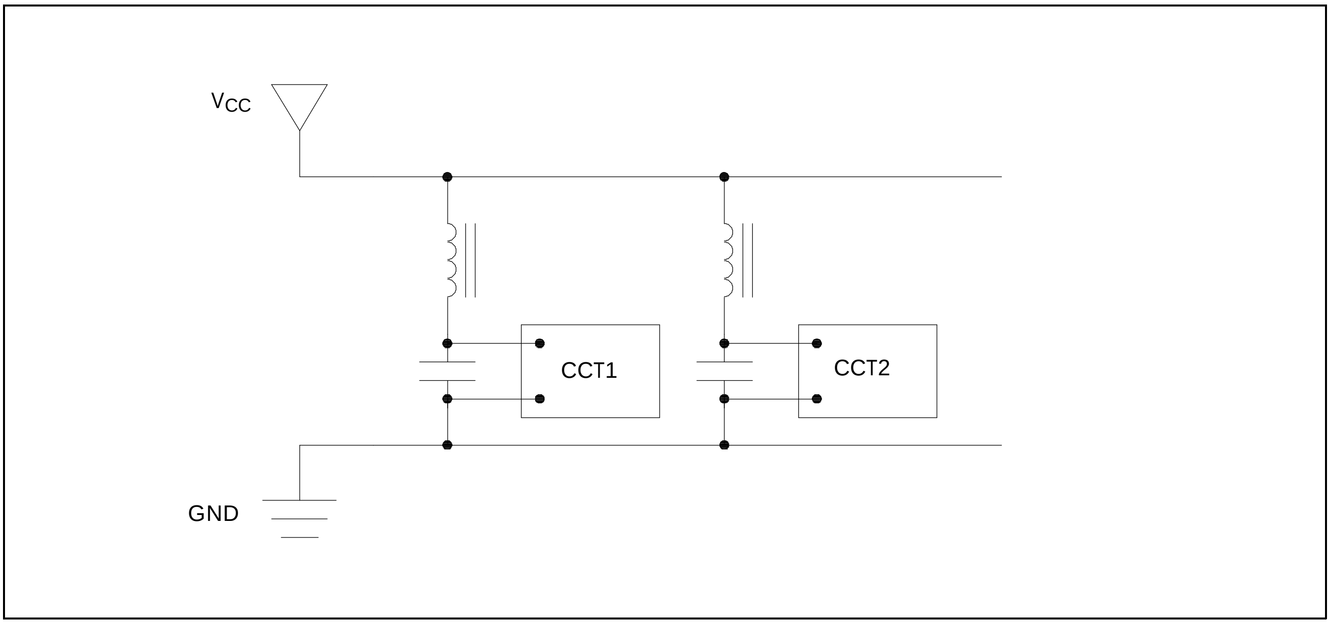


Figure 19 : *Decouple Supply Lines at Local Boundaries*

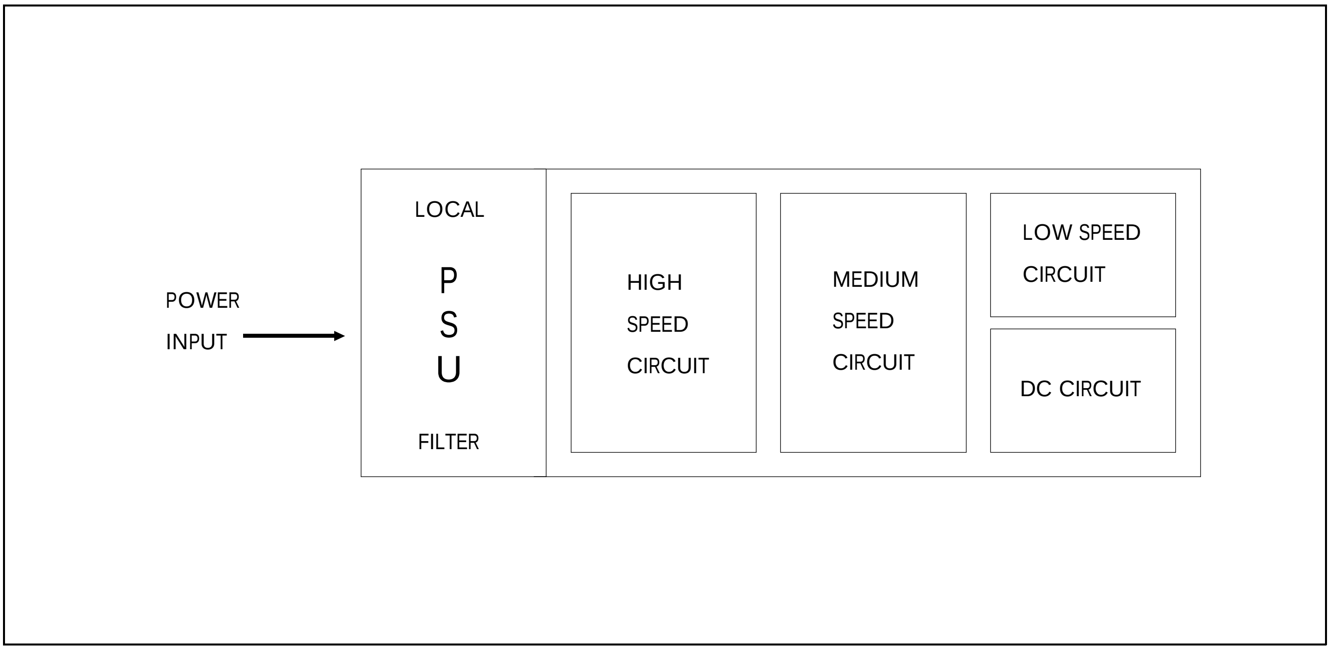


Figure 20 : *Place High Speed Circuit Close to PSU*

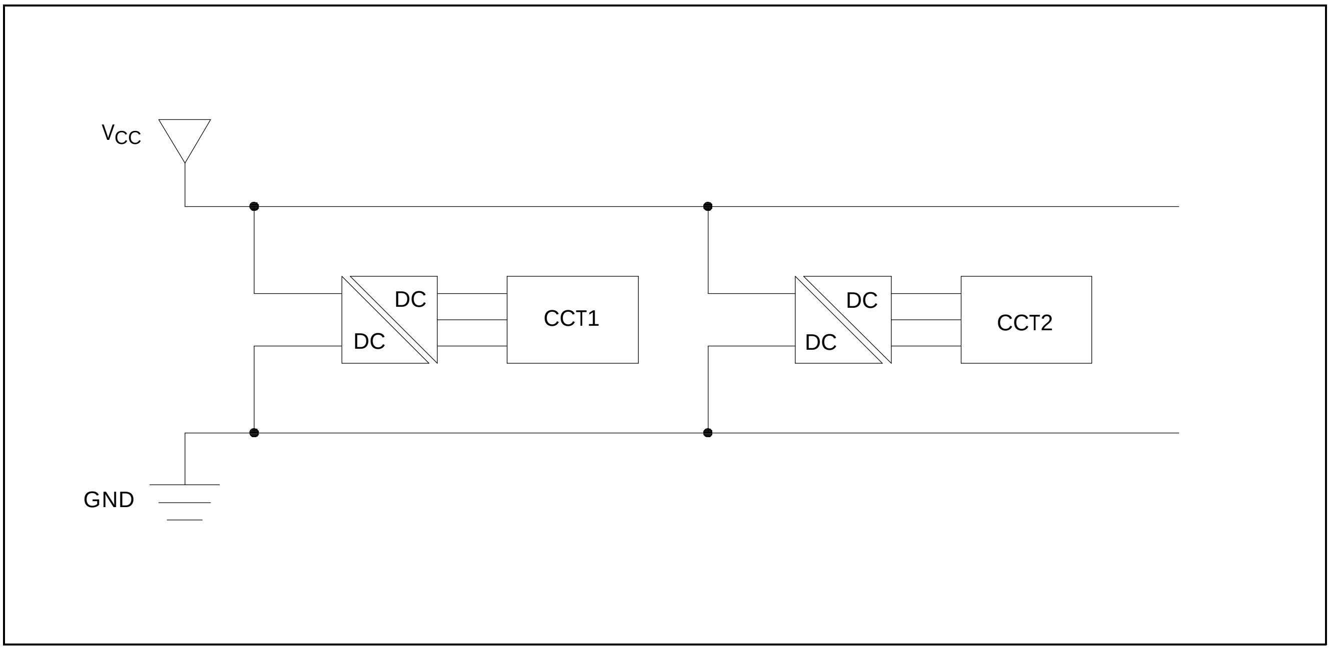


Figure 21 : *Isolate Individual Systems*

conducted and radiated emissions

There are basically two types of emissions covered by the EC directive on EMC, radiated and conducted. Conducted emissions are those transmitted over wire connecting circuits together and covers the frequency spectrum 150kHz to 30MHz. Radiated are those emissions transmitted via electromagnetic waves in air and cover the frequency spectrum 30MHz to 1GHz. Hence the EC directive covers the frequency spectrum 150kHz to 1GHz, but as two separate and distinct modes of transmission.

Newport Components range of DC-DC converters feature toroidal transformers within the component. These have been tested and proved to have negligible radiated noise. The low radiated noise is primarily due to toroidal shaped transformers maintaining the magnetic flux within the core, hence no magnetic flux is radiated by design. Due to the exceptionally low value of radiated emission only conducted emissions are quoted.

Conducted emissions are measured on the input DC supply line. Unfortunately no standards exist for DC supplies as most standards cover mains connected equipment. This poses two problems for a DC supplied device, firstly no standard limit lines can be directly applied, since the DC supplied device does not directly connect to the mains, also all reference material uses the earth-ground plane a reference point. In a DC system often the 0V is the reference, however, for EMC purposes, it is probably more effective to maintain the earth as the reference, since this is likely to be the reference that the shielding or casing is connected to. Consequently all measurements quoted are referenced to the mains borne earth.

line impedance stabilisation network (LISN)

It is necessary to ensure that any measurement of noise is from the device under test (DUT) and not from the supply to this device. In mains connected circuits this is important and the mains has to be filtered prior to supply to the DUT. The same approach has been used in the testing of DC-DC converters and the DC supply to the converter was filtered to ensure that no noise from the PSU as present at the measuring instrument.

A line impedance stabilisation network (LISN) conforming to CISPR 16 specification is connected to both positive and negative supply rails and referenced to mains earth (see figure 22). The measurements are all taken from the positive supply rail with the negative rail measurement point terminated with 50W to impedance match the measurement channels.

shielding

At all times the DUT, LISN’s and all cables connecting any measurement equipment, loads and supply lines are shielded. The shielding is to prevent possible pick-up on cables and DUT from external EMC sources (e.g. other equipment close by). The shielding is referenced to mains earth (see figure 22).

line spectra of DC-DC converters

All DC-DC converters are switching devices, hence, will have a frequency spectra. Fixed input DC-DC converters have fixed switching frequency, for example the NMH range of converters has a typical switching frequency of 75kHz. This gives a stable and predictable noise spectrum regardless of load conditions.

If we examine the noise spectrum closely (see figure 23) we can see several distinct peaks, these arise from the fundamental switching frequency and its harmonics (odd labelled line spectra) and the full rectified

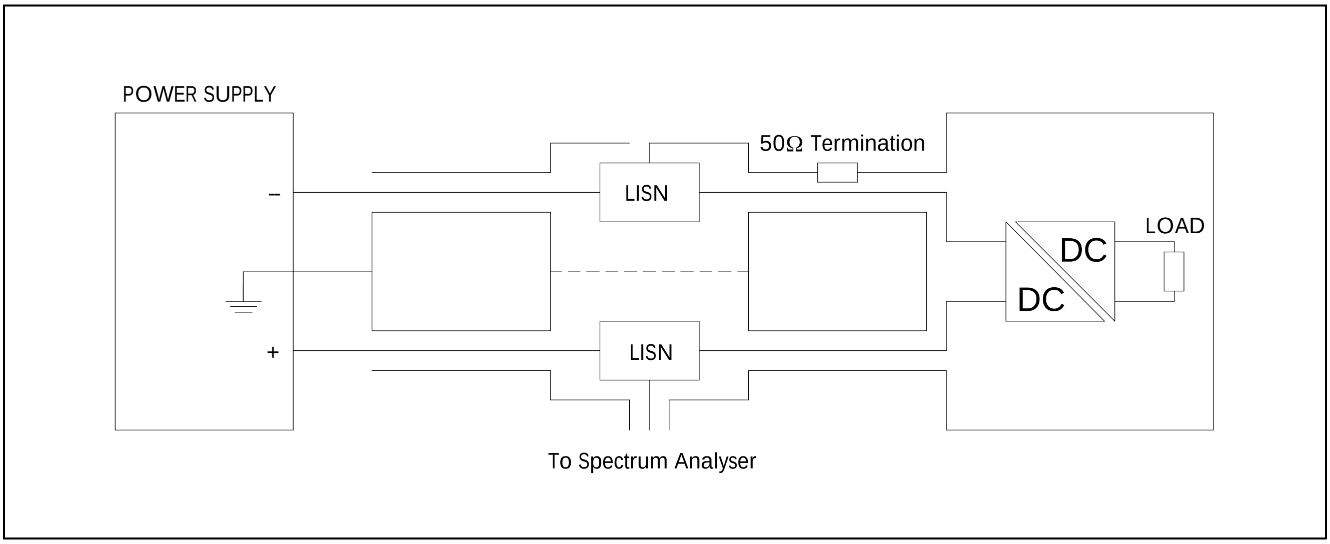


Figure 22 : *Filtered Supply to DC-DC Converter*

spectra at twice the fundamental switching frequency (even labelled line spectra). Quasi-resonant converters, such as the Newport range, have square wave switching waveforms, this produces lower ripple and a higher efficiency than soft switching devices, but has the drawback of having a relatively large spectrum of harmonics.

The EC regulations for conducted interference covers the bandwidth 150kHz to 30MHz, considering a converter with a 100kHz nominal switching frequency, this would exhibit 299 individual line spectra. There will also be a variation of absolute switching frequency with production variation, hence a part with a 90kHz nominal frequency would have an additional 33 lines

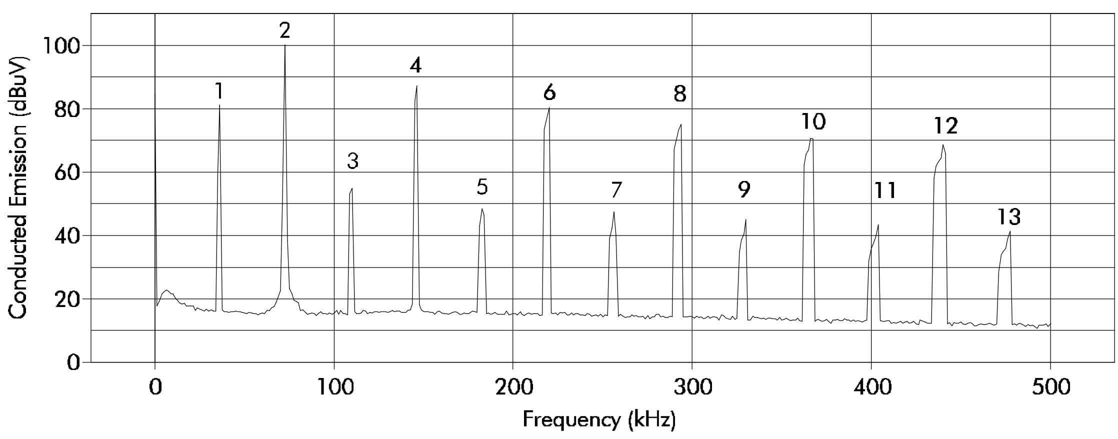


Figure 23 : *Individual Line Spectra*

over the entire 30MHz bandwidth. Absolute input voltage also produces slight variation of switching frequency (see figure 24). Hence, to give a general level of conducted noise, we have used a 100kHz resolution bandwidth (RBW) to examine the spectra in the data sheets. This wide RBW gives a maximum level over all the peaks, rather than the individual line spectra, this is easier to read as well as automatically compensating for variances in switching frequency due to production variation or differences in absolute input voltage (see figure 25).

The conducted emissions are measured under full load conditions in all cases, under lower loads the emission levels do fall, hence full load is the worst case condition for conducted line noise.

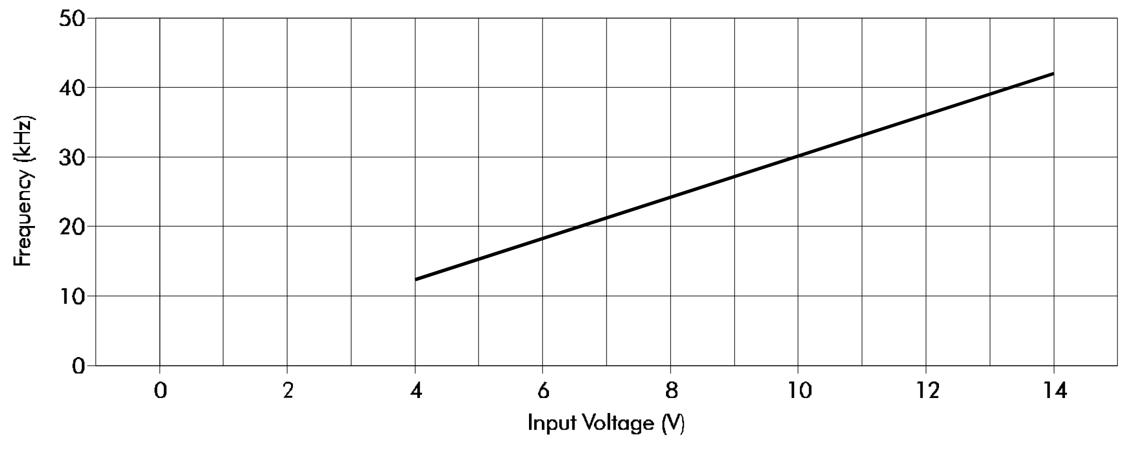


Figure 24 : *Frequency Voltage Dependency*

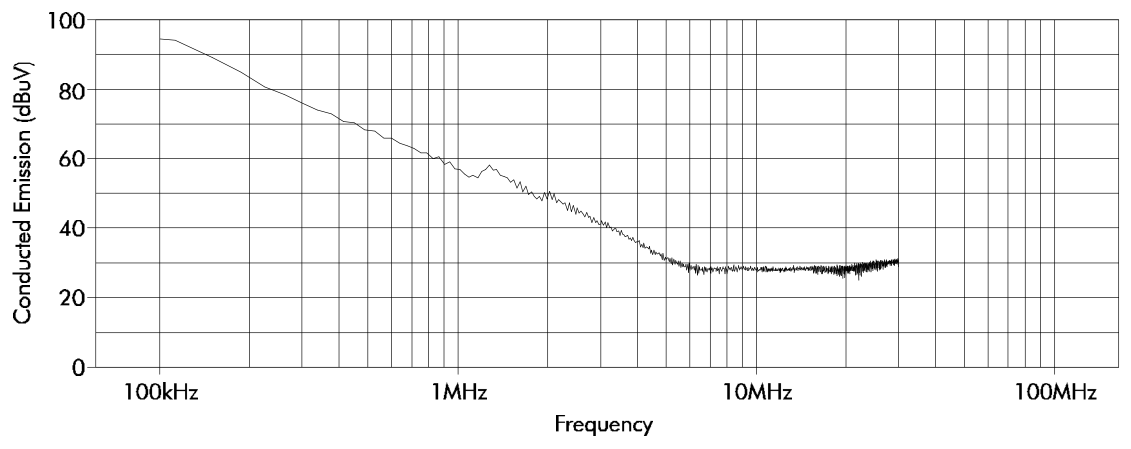


Figure 25 : *NMS Spectrum*

temperature performance of DC-DC converters

The temperature performance of the DC-DC converters detailed in this book is always better than the quoted operating temperature range. The main reason for being conservative on the operating temperature range is the difficulty of accurately specifying parametric performance outside this temperature range.

There are some limiting factors which provide physical barriers to performance, such as the Curie temperature of the core material used in the DC-DC converter (the lowest Curie temperature material in use at Newport Components is 125°C). Ceramic capacitors are used almost exclusively in the DC-DC converters because of their high reliability and extended life properties, however, the absolute capacity of these can fall when the temperature rises above 85°C (ripple will increase). Other considerations are the power dissipation within the active switching components, although these have a very high temperature rating, their current carrying capacity derates as temperature exceeds 100°C.

Therefore this allows the DC-DC converters to be used above their specified operating temperature, providing the derating of power delivery given in the specification is adhered to. Components operating outside the quoted operating temperature range cannot be expected to exhibit the same parametric performance that is quoted in the specification.

An indication of the stability of a device can be obtained from the change in its operating frequency as the temperature is varied (see figure 26). A typical value for the frequency variation with temperature is 0.5% per °C, a very low value compared to other commercial parts. This illustrates the ease of filtering of Newport Components DC-DC converters since the frequency is so stable across load and temperature ranges.

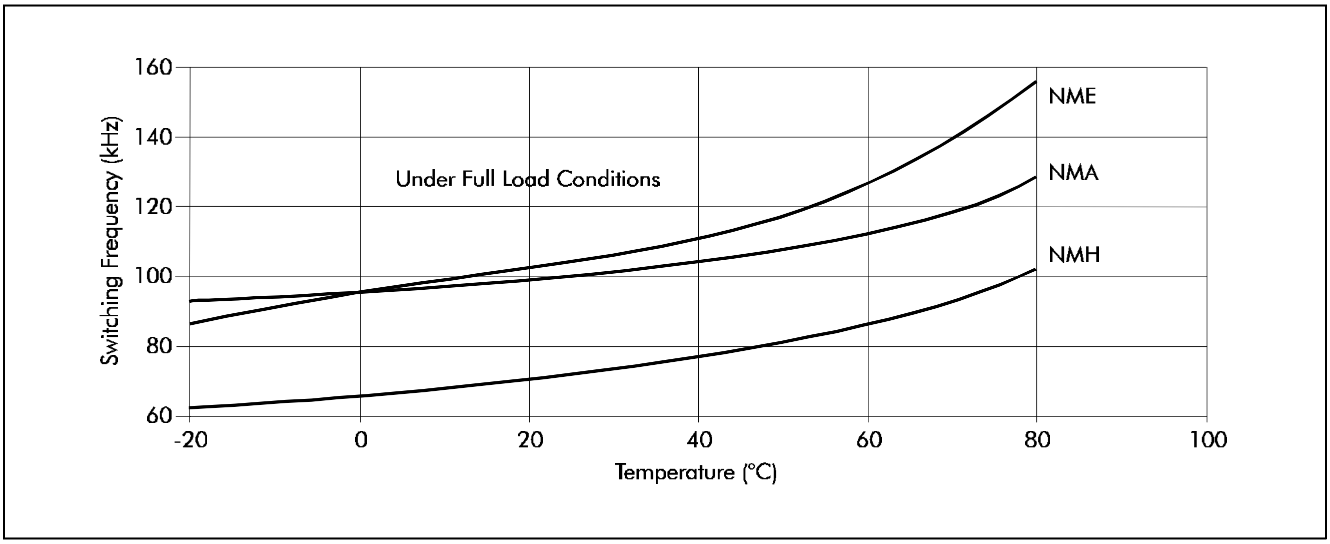


Figure 26 : *Typical Switching Frequency vs. Temperature*

transfer moulded surface mount DC-DC converters

production guideline application note

The recent introduction by Newport Components Ltd (NCL) of a new and innovative method of encapsulating hybrid DC-DC converters in a transfer moulded (TM) thermoset epoxy plastic has enabled a new range of surface mount (SM) DC-DC converters to be brought to market which addresses the component placement with SOIC style handling.

With any new component there are of course new lessons to be learnt with the mounting technology. With the new TM range of DC-DC converters, the lessons are not new as such, but may require different production techniques in certain applications.

component materials

The body of the TM product range is a high thermally conductive thermoset epoxy plastic.The advantage of thermoset materials in this application is that the body does not deform under post-cure heat cycles (i.e. under high temperature reflow conditions). Consequently there are no precautions required to protect the body during reflow. Other manufacturers components using thermoplastics may deform or require a heat shield during the reflow process.

The lead frame is a copper material, hence has a high conductivity and reduces the internal resistance of tracking within the DC-DC converters. Hybrid designs which use film deposition for tracking (or printed inks) feature higher losses within the DC-DC converter due to their higher resistance.

The leads are tinned with a 60:40 lead-tin (Pb:Sn) solder finish. This is a standard lead finish and compatible with virtually all solder mixes used in a production environment.

component placement

The TM ranges are designed to be handled by placement machines in a similar way to standard SOIC packages. The parts are available either in tubes (sticks) or in reels. The parts can therefore be placed using machines with either vibrational shuttle, gravity feeders or reeled feeders.

The vacuum nozzle for picking and placing the components can be the same as used for a standard 14 pin or 18 pin SOIC (typically a 5mm diameter nozzle). An increase in vacuum pressure may be beneficial due to the heavier weight of the hybrid compared to a standard SOIC part (a typical 14 pin SOIC weighs 0.1gm, the NMETM DC-DC converter weighs 1.3gm). It is advisable to consult your machine supplier on choice of vacuum nozzle if in doubt.

If placing these components by hand, tweezer on the central body area where there are no component pins. Tweezering on the pins can cause bending and the pin co-planarity could be compromised.

component alignment

The components can be aligned by either optical recognition or tweezering. If using tweezer alignment it should be ensured that the tweezers are aligning on the component body and not on the pins. The components themselves are symmetrical in the body, hence relatively easy to align using either method.

solder pad design

The TM range of DC-DC converters are designed on a pin pitch of 1.27mm (0.05") with 1mm pad widths and 1.75mm pad lengths. This allows pads from one part to be used within a PCB CAD package for forming the pad layouts for other NCL TM parts. These pads are wider than many standard SOIC pad sizes (0.64mm) and CAD packages may not accommodate these pins with a standard SOIC pad pattern. It should be remembered that these components are power supply devices and as such need wider pads and thicker component leads to minimise resistive losses within the interconnects.

Pad patterns for each component are included in the relevant chapter. These should be followed where appropriate.

One of the benefits of the NCL approach is that PCB layout can be produced for dual component usage. For example the NMATM dual output DC-DC converter pad layout can accommodate the NMETM product to give a single positive output voltage only, without any PCB tracking changes.

solder reflow profile

The TM range of components supplied by NCL are designed to withstand a maximum reflow temperature of 280C in accordance with CECC 00802. If multiple reflow profiles are to be used (i.e. the part is to pass though several reflow ovens), it is recommended that lower ramp rates be used than the maximum specified in CECC 00802, continual thermal cycling to this profile could cause material fatigue if more than 5 maximum ramp cycles are used.

In general these parts will exceed the reflow capability of most IC and passive components on a PCB and should prove the most thermally insensitive component to the reflow conditions.

adhesive requirements

If SM components are going to be wave soldered (i.e. in a mixed through hole and SM PCB) or are to be mounted on both sides of a PCB, then it is necessary to use an adhesive to fix them to the board prior to reflow. The adhesive prevents the SM parts being ’washed off’ in a wave solder, and being ’vibrated off’ due to handling on a doubled sided SM board.

As mentioned previously, the NCL range of SM DC-DC converters are heavier than standard SOIC devices. The heavier weight is a due to the size (volume) and internal hybrid construction. Consequently the parts place a larger than usual stress on their solder joints and leads if these are the only method of attachment. Using an adhesive between component body and PCB can reduce this stress considerably. If the final system is to be subjected to shock and vibration testing then using adhesive attachment is essential to ensure the parts pass these environmental tests.

The TM range of DC-DC converters from NCL all have a stand-off beneath the component for the application of adhesive to be placed without interfering with the siting of the component. Method of adhesive dispensing and curing, plus requirements for environmental test and in-service replacement will determine suitability of adhesives rather than the component itself. However, having a thermoset plastic body, thermoset epoxy adhesive bonding between board and component is the recommended adhesive chemistry.

If the reflow stage is also to be used as a cure for a heat cure adhesive, then the component is likely to undergo high horizontal acceleration and deceleration during the pick and place operation. The adhesive must be sufficiently strong in its uncured (green) state in order to keep the component accurately placed.

adhesive placement

The parts are fully compatible with the 3 main methods of adhesive dispensing; pin transfer, printing and dispensing. The method of placing adhesive will depend on the available processes in the production line and the reason for using adhesive attachment. For example if the part is on a mixed though-hole and SM board, adhesive will have to be placed and cured prior to reflow. If using a SM only board and heat cure adhesive, the reflow may be used as the cure stage. If requiring adhesive for shock and vibration but using a conformal coat, then it may be possible to avoid a separate adhesive all together and the coating provides the mechanical restraint on the component body.

Patterns for dispensing or printing adhesive are given for automatic lines. If dispensing manually after placement the patterns for UV cure are easily repeated using a manual syringe (even if using heat cure adhesive). If dispensing manually dot height and size are not as important and the adhesive should be applied after the components have been reflowed. When dispensing after reflow, a chip underfill formulation adhesive would be the preferred choice, these types 'wick' under the component body and offer a good all round adhesion from a single dispensed dot.

The patterns shown allow for the process spread of the stand-off on the component, but do not account for the thickness of the PCB tracks. If thick PCB tracks are to be used a grounded copper strip should be laid beneath the centre of the component (care should be exercised to maintain isolation barrier limits). The adhesive should not retard the pins reaching their solder pads during placement of the part, hence low viscosity adhesive is recommended.

The height of the adhesive dot, its viscosity and slumping properties are critical. The dot must be high enough to bridge the gap between board surface and component, but low enough not to slump and spread, or be squeezed by the component and so contaminate the solder pads.

If wishing to use a greater number of dots of smaller diameter (common for pin transfer methods) the dot pattern can be changed by following a few simple guidelines. As the number of dots is doubled their diameter should be halved and centres should be at least twice the printed diameter from each other, but the dot height should remain at 0.4mm. The printed dot should always be positioned by at least its diameter from the nearest edge of the body to the edge of the dot. The number of dots is not important provided good contact between adhesive and body can be guaranteed, but a minimum of 2 is recommended.

cleaning

The thermoset plastic encapsulating material used for the NCL range of surface mount DC-DC converters is not fully hermetically sealed. As with all plastic encapsulated active devices, strongly reactive agents in hostile environments can attack the material and the internal parts, hence cleaning is recommended in inert solutions (e.g. alcohol or water based solvents) and at room temperature in an inert atmospheres (e.g. air or nitrogen).

A batch or linear aqueous cleaning process would be the preferred method of cleaning using a deionised water solution.

custom DC-DC converters

In addition to the standard ranges shown in this data book, Newport Components have the capability to produce custom DC-DC converters designed to your specific requirements. In general, the parts can be rapidly designed using computer based CAD tools to meet any input or output voltage requirements within the ranges of Newport Components standard products (i.e. up to 48V at either input or output). Prototype samples can also be produced in short timescales.

Custom parts can be designed to your specification, or where the part fits within a standard series, the generic series specification can be used. All custom parts receive the same stringent testing, inspection and quality procedures as standard products.

Newport Components custom parts are used in many applications which are very specific to the individual customer, however, some typical examples are;

ECL Logic driver
Multiple cell battery configurations
Telecommunications line equipment
Marine apparatus
Automotive electronics
LCD display power circuitry
Board level instrumentation systems

To discuss your custom DC-DC converter requirements, please contact Newport Components technical support desk or your local distributor.