Custom DC-DC Converters

Overview

The availability of custom hybrid DC-DC Converter configurations can add value to many applications, even though a custom converter generally costs more than a standard part. The user should evaluate the costs and benefits of a custom approach when warranted by the application. Customers are often unaware that hybrid DC-DC Converters can be readily modified. The use of modified converters can cut cost, size, weight and improve efficiency.

A single converter can provide a high multiplicity of outputs, using just one part to provide what might have required two or three packages. Or, in assemblies of multiple converters, custom configurations can reduce the overall package count. This can cut cost, increase reliability, save size, weight and efficiency.

In low power applications, even the smallest DC-DC Converter may have several hundred milliwatts of quiescent losses. Therefore, reducing the number of converters required to implement a requirement can be vastly more efficient using one custom converter with many outputs. Special voltage trims can also reduce or eliminate the need for external circuits, post regulators or add voltage margin for external redundant diode OR schemes.

In high power applications, two or more hybrid DC-DC Converters may be needed to achieve a given output power level. When using multiple converters, it is always desirable that they share power loading. At a high enough output voltage, it is often more desirable to place multiple converters in series rather than in parallel. The series connection provides virtually perfect power sharing without any additional circuitry. When a series connection of converters is used, it is very often desirable to have a non-standard output voltage so that the sum of the output voltages adds up to the desired amount.

Some requirements, such as power converters for MESFET RF amplifiers, need outputs which are sequenced. MDI can provide the sequencing as part of the converter.

MDI can provide DC-DC Converters whose outputs can be adjusted over a wide range, or converters that provide a constant current output with a voltage limit. Adjustable voltage converters are frequently used to program RF amplifier power levels or as lighting controllers. Constant current output converters are frequently used to charge capacitor banks.

Other design possibilities for custom DC-DC Converters include unique input voltages, ultra low output ripple, telemetry functions and BIT functions.

The following modifications are classified in order of ascending cost and lead time:

A. Minor voltage trim: An output voltage adjustment to an otherwise standard part that can be performed using a laser trim or chip resistor. The transformer windings stay Q unchanged.

B. Major voltage change: An output voltage adjustment to an otherwise standard part that requires a transformer winding change, and may also include requirements for different output rectifiers, output capacitors and output filters. However, a standard substrate is used.

C. Minor substrate change: A modification to an otherwise standard part that can be performed using wire bonding or internal wiring. The substrate wiring is changed via laser cut and wire or wire bond jumper techniques. The magnetic components usually stay unchanged.

D. Major substrate change: The designer essentially starts with a clean sheet, but may drop in proven circuit and functional blocks from existing designs. A major substrate change often requires two iterations.

Unique Input Voltage

MDI's standard product range includes the following:

8-40 VDC	a 5:1 range	16 to 24 VDC nominal
16-50 VDC	a 3.125:1 range	28 VDC nominal
86 to 158 VDC	a 1.8372:1 range	120 VDC nominal
200 to 335 VDC	a 1.675:1 range	270 VDC nominal

Within these ranges are the absolute gaps of 50 to 86 VDC and 158 to 200 VDC.

In addition to the gaps mentioned above, it is less than ideal to unnecessarily operate a DC-DC Converter near its operating limits. Each of the converter types has been designed to be optimum for the nominal voltage indicated, and provide a specified level of performance at the voltage extremes. This implies that the performance of a part may be less than optimum near the extremes of a part's range. Performance fall off can include efficiency, regulation, dynamic response, loop stability, ripple voltage and component derating.

Although a converter may operate near or at the edge of its rating, it is unwise to do so when the nominal conditions are close to the ratings. Instead, it is prudent to rewind the magnetic components and to otherwise change the design so that the converter is again optimized for the nominal input conditions.

Similarly, converters may be produced which operate over wide extremes of voltage, 10:1 ranges and greater. However, such wide operating ranges place great stresses on components. Consequently, severe derating must be used. This results in power levels for a given package size that are lower than obtainable with a standard input voltage range.

Unique Output Voltage

To obtain a unique output voltage that brackets an existing output rating, the output may either be trimmed or may require a transformer change. Most MDI hybrid DC-DC Converters have an output referenced sensing circuit. For most of the standard output voltages, the output sensing circuit is self powered directly from the output voltage. For units with a very low output voltage (less than 5 VDC) or a high output voltage (above 28 VDC), the output sensing circuit must be powered by a separate winding. This configuration exists in most MDI converter designs. However, for outputs beyond the range of self powering, a unique transformer design is normally required to derive the correct voltage for the output sensing circuit in reference to the output voltage.

Unique output voltages can include unique dual output converters and unique triple output converters. Here are some examples:

A dual output converter that produces +12 VDC and +5 VDC.

A dual output converter that produces +5 VDC and -5.2 VDC.

A dual output converter that produces +5 VDC and +3.3 VDC.

Triple output converters can be advantageously used to provide a dual output where one output has relatively low current. For example:

A dual output converter that produces +5 VDC at high current and +24 VDC at low current (This is a standard T12 configuration where the 24 is the sum of +/-12 VDC).

Triple output converters can be modified so that the main output can be a voltage other than 5 VDC. For example, a converter can produce +28 VDC at high power, +/- 15 VDC at low power. The low power outputs are independently regulated and isolated from the high power winding.

Triple output converters can also be modified to produce two auxiliary outputs with a positive polarity. The auxiliary voltages can be dissimilar.

Low Output Ripple

All MDI DC-DC Converters have an output common mode inductor to reduce output spikes. The common mode inductor is designed to have low differential inductance because output voltage is sensed beyond this inductor, at the output pins. However, it is possible to trade some slightly increased load regulation for a lower fundamental output ripple by internally rewiring the converter's sense point and increasing the differential output inductance.

This technique works well provided the effects of AC modulation on the DC input line (ie., conducted susceptibility) do not predominate in the output ripple response.

MDI has also provided output filter hybrids, which are capable of reducing output ripple and noise to extremely low levels.

High Audio Rejection

Some applications require a very high degree of isolation from input effects to the output voltage. A conventional DC-DC Converter with current mode feedback will provide 50 dB to 60 dB of audio rejection from input to output. The EMI filter typically adds (ie., reduces the rejection) by 10-20 dB at certain frequencies.

If the rejection is desired at low or audio frequencies, the rejection provided by a single regulating loop might not be sufficient. In this event, a second regulating loop is required. While the primary regulating loop is always the pulse width modulation (PWM) loop, the second regulating loop can be either switching or linear. For example, in a system two converters may be cascaded. While this is usually a bad practice in most instances (see application note on cascaded converters), one benefit that is provided by cascaded converters is the reduction of audio susceptibility.

In a standard triple output converter manufactured by MDI, the main output is PWM regulated and the auxiliary outputs are linear regulated from header voltages derived from the main output. This is an example of dual regulating loops. There will be an extremely high audio rejection on the auxiliary outputs because of the two regulating loops in series.

In constructing higher power solutions with high audio susceptibility rejection, a low drop out linear regulator stage is still useful. This may either be incorporated within the hybrid or be external. When the regulator is external, the output voltage of the hybrid DC-DC Converter may be increased to provide adequate head room for the regulator's operation.

Output Sequencing

DC-DC Converters frequently power GaAs FET RF solid state power amplifiers (SSPA's). MDI has designed and manufactured many different DC-DC Converters for driving GaAs FET SSPA's in space applications, using several different topologies for this purpose. These amplifiers require that on turn on, the negative gate bias voltage appears first before the positive drain voltage is applied. On turn off, the negative gate bias must remain on while the positive drain voltage is removed.

The basic power converter for higher power SSPA applications (up to 100 watts in hybrid form) is derived from a unique MDI model originally used to power the main X band SSPA in the JPL Mars Pathfinder project.

The key features of the higher power design are as follows:

1. The power stage topology is a 200 kHz. current mode flyback converter, which has good rejection of input variations.

2. A single flyback converter stage is used for all positive and negative outputs.

3. Output sequencing and inhibit is achieved with output FET switches.

The basic power converter topology for the lower power (up to 30 watts in hybrid form) SSPA applications is derived from an MDI model originally used to power a backup SSPA in a space application. The low power topology has fewer parts, so it is more suited for low power applications. However, there is slightly less control over the sequencing delays than the higher power topology. The basic low power sequenced topology is a 200 kHz. current mode flyback converter, combined with a low power forward output. This combination of flyback and forward modes allows a naturally simple sequencing with a minimum of parts.

The negative output voltage is derived from a forward connected winding, also using a linear regulator. The positive outputs are derived from flyback windings. The principal of this topology relies on obtaining tight coupling between the flyback transformer primary and the forward winding. The initially very narrow spikes of the FET are peak detected and allow the forward voltage to appear first at turn on. The flyback voltages rise more slowly. This creates the turn on delay.

When power is removed, hold up capacitance supplies the negative output while the other outputs decay.

Since sequenced hybrid DC-DC Converters are not listed in MDI's catalog, consult MDI's sales and marketing department for specific requirements. The sequenced converter needed for your application may have been previously developed.

Adjustable Output Converters

Many applications require a variable output voltage that is commanded by an external signal. The signal is usually a voltage referenced to the output return. Applications for variable output converters include adjustable RF amplifiers, lighting controls, capacitor charging power supplies, battery chargers and constant current sources. The topology of the standard MDI hybrid DC-DC converters is a current mode flyback. This topology is highly suited for achieving a wide operating range, so is a good choice for an adjustable output unit.

MDI's standard hybrid DC-DC Converters are designed primarily for a fixed output voltage. Adjustments of up to ten percent in the nominal output voltage are achievable without unduly compromising the operating points. The standard converter design relies on the relatively fixed output voltage. For maximum efficiency, the input PWM stage is started by a transistor connected to the input line, but powered by a housekeeping winding when the converter operates. Similarly, the output voltage sensing circuitry is normally self powered from the output. If the output voltage varies considerably, the housekeeping winding will not be available to power the input PWM circuitry and the output voltage will not be available to power the output sensing circuitry.

To obtain a variable voltage converter, the start up circuit must be modified so that it powers the input PWM circuitry at all times. This results in slightly lower efficiency. In addition, the output sensing circuitry must be powered by a separate winding, as it usually cannot be self powered if the output voltage varies significantly. If the input voltage variation is relatively low, the output sensing circuits can be powered from a forward phased winding. Alternatively, a flyback phased winding with a linear regulator may be used.

To extend the operating range, it is sometimes advantageous to program the operating frequency downward as the output voltage is programmed downward. This gives an enhanced dynamic range.

Current sources derived from hybrid DC-DC Converters are similar to adjustable output DC-DC Converters. In this case, the output current is sampled and compared to a reference. The amplified error voltage between the reference and the measured current is used to drive an adjustable output DC-DC Converter. It is also possible, by varying the reference voltage, to obtain an adjustable constant current source.

Because of the flyback topology and construction techniques used, MDI's product line lends itself to economically producing custom configurations. This can include special packages, up to ten regulated outputs, units with hold up, units with telemetry, low power with high efficiency and also DC to AC inverters.