Remote Sense Techniques

Abstract: This paper will give the reader an insight into the different options available for remote sensing the positives and negatives associated to each approach. It also reviews how the implementation can effect stability and how we can overcome these application issues.

Background:

As is often required in high current and high load transient applications, the optimum solution is to place the converter *'on top of'* the required load. However, the question of locating a   power supply in close proximity to the required load is not a trivial one. Product designers may not have this luxury, which can result in the product being placed some distance away from the load. This may effect the performance of the product. With this in mind, compensation can be made for this occurrence at the time of design. High frequency components can be handled with the use of local decoupling capacitors. Whereas low frequency voltage drops on cables can, to a large degree, be compensated for by the use of remote sensing to compensate for losses. How you choose to implement remote sense on a design can have a significant effect on how it will perform in a customer application, and is something that is discussed in a bit more detail here.

Introduction:

Remote sensing can pose stability problems, as the compensation loop must be stable under large load variations and with different track impedance characteristics. In special cases the remote sense circuit may need to be adapted to the final working conditions. We look at a number of ways a designer can choose to invoke a remote sense option, and the resulting impact each option will have as the module is integrated into an application.

1.1 : Local sense only

Local sense is where the module will regulate around the output pins only. No compensation available for voltage drops on application. This will result at minimum, voltage drops from module to load, and there will be a general degradation in performance between the output pins of the module and the load. Parasitics in pins and tracks means that there will also probably be some degradation in load step transient response. This effect will be amplified as the output current load and load step increases.

1.2: Partial remote sense.

One way to improve on this is to use a positive sense pin invoked only. Local ground is used on module, and a positive sense pin allows the user to sense on the positive output of the load. This allows a compensation for voltage drops from module to load. Invoking a positive sense pin will reduce the impact of parasitics as outlined above but only by a factor of 50%. In order to improve on transient response the user will need to place extra capacitance at the load, which will reduce the phase margin of the design and may lead to instability.

1.3: Full remote sense, bulk capacitance onboard

This remote sense set-up involves sensing from the positive node and the ground of the load. If the output load is in the region of uH there may be a reduced impact of creating essentially an LC in series with an LC which is a fourth order filter on output. However if your design has an output choke in the nH region, the parasitic inductance introduced by having the power supply a significant distance away from the load may introduce an oscillator effect. All parasitics are part of the control loop and must be taken into consideration in stabilising the control loop. With this approach we can eliminate any parasitic issues under static load, but transient responses can be impacted on by this approach.

1.4 : Full remote sense, capacitance at load

If we use the option of placing all output capacitance at the load we can reduce the effect on transient response. Now we have the same set-up as in option three above, but this time we only have some high frequency capacitors on the modules, with all other capacitors placed at the load. In

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taking this approach we restore a second order filter characteristic while at he same time improving the transient response, and retaining the static load performance. The issue with moving the all of output capacitance to the load means ripple current loops now are increased which could lead to other issues with EMI. At minimum this design will have high frequency caps onboard for EMI reduction. However, this approach is not without due considerations.
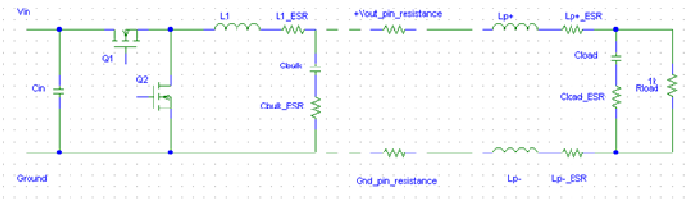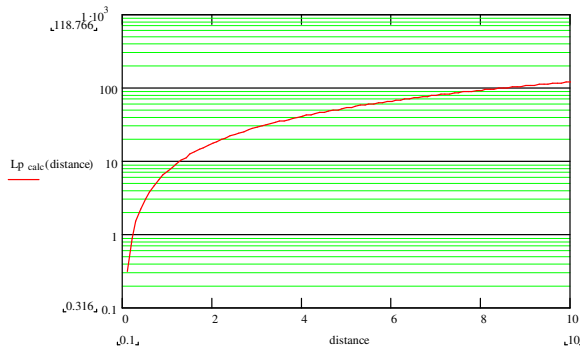

Fig 1: Theoretical calculation of parasitic inductance V's distance from load.

The plot in figure 1 shows how the parasitic inductance can increase as the distance from module to load in increased. The y-axis shows the parasitic inductance in nH , while the x-axis shows the distance from load in cm's. However this approach now means that the role of the power supply designer and application designer overlaps. In the past power supply designers would have designed a stable system and published say maximum capacitive load capabilities. However faster transient demands are typically at a higher switching frequency. This means a reduction in the inductance of the onboard choke. So now the track inductance between output and load are an integral part of the control loop. We could realistically have over 50nH of parasitic inductance between module and load. (A calculated figure for inductance for the load 5cm from the output of the module can be in the region of 52nH). If for example the output choke is say 100nH, we have now unwittingly increased the choke by a factor of 50%. In figure 1 above we plot the theoretical parasitic inductance that could be inadvertently introduced into the control loop.

2: Mathematical analysis of each approach.

Lets try to quantify each approach with some frequency domain analysis.

The circuit used to describe the analysis is outlined in figure 2 below.

Fig 2 : Circuit used for analysis

If we complete a closed loop analysis of each set-up we can see quickly how each approach can effect the stability of the design.
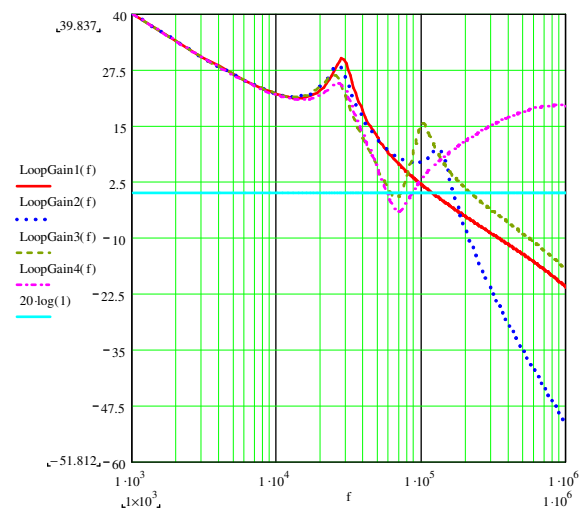

Fig 3: Gain V's frequency of 4 options as described above.

Figure 3 above shows the gain v's frequency of each option. Here we have set the compensation network on each design as a constant as we see how each approach effects the overall system.
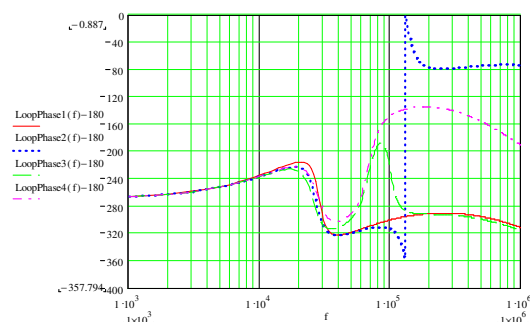

Fig 4: Phase margin of 4 options as described above.

The corresponding phase margin can change from a very stable 90° down to 45° depending on the remote sense option invoked. In the calculations we have assumed a parasitic inductance of 50nH. If as

a designer you don't account for this potential delta at time of design, then it may lead to instability when integrated into an application. Further changes in parasitic components may lead to instability.

In a working design it would be a trade off between optimising your design and achieving the best performance at the load (regulation and transient response). The most likely end solution would be a combination of option 3 and four above. This means place as little capacitance onboard and as much capacitance as close to the load. The objective is to retain a second order filter on the output. The optimum design can be achieved by getting this balance right.

3: Can remote sensing improve on efficiency measurements?.

Efficiency can be improved by as much as 1% at full load by invoking the optimum design, which is a combination of option three and four. We see in fig 6 below in which option 3 , 4 and a balance of the two approaches can effect overall efficiency. Measurements below were taken from the output stage of the two Xg5's in parallel. Each of the PowerMods was set to 48 Volts, and delivered a combined power of 576 Watts to the load.
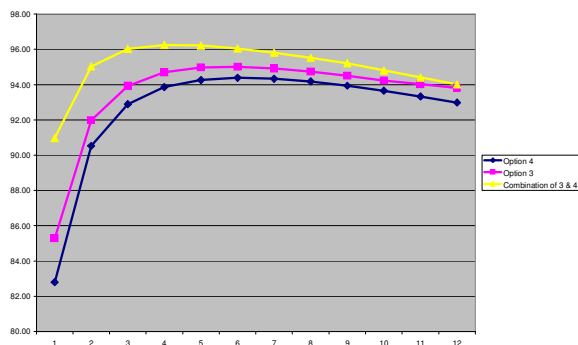

Fig 6: Measured efficiency plots of a module design with various options invoked.

This needs to be tempered with the trade-off's required to achieve this maximum figure. Here we have placed a minimum capacitance at the power pins, and define the required capacitance at the load. This maximises the response capabilities for load transients whilst maintaining a conversion efficiency of *95%*

Summary & Conclusions:

The remote sense compensation feature minimises the effect of resistance in the distribution system and facilitates accurate voltage regulation at the load terminals or another selected point. The nature in which a design invokes this can have an impact on the performance of the module in an application. We have discussed in some detail the key points that must be taken into consideration when choosing the approach that suits the required performance of the finished product. Remember that the remote sense line(s) will carry very little current and hence will not require a large cross-sectional area. However, if the sense line is routed on a PCB, it should be located close to a ground plane in order to minimise any noise coupled onto the lines that might impair control loop stability. If using a pair of wires these should be brought out from the Xgen in a twisted pair configuration. Recall that when using remote sense compensation all the resistance, parasitic inductance and capacitance of the distribution system are incorporated into the feedback loop of the power module. The choice of remote sense should be based on how your design is required to perform in an application. Each of the approaches outlined will have their positives and negatives. In order to avail of the advantages and compensate for the disadvantages you must be aware of them in the first place. Tight load regulation, good static performance, overall efficiency, optimum transient performance *can* be achieved in an application, if informative design choices are made at concept phase of the power supply design.