Freescale Semiconductor
Application Note

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Designing a Core Power Supply for MSC8144 DSPs

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This application note describes guidelines for developing an MSC8144 core power supply system. The MSC8144 four-core DSP can consume up to 8 A of current from a 1.0 V power supply. These two factors, a low voltage level and a relatively high current, require special considerations when designing the core power system. The several factors to consider when designing the power system include the following:

- Power supply accuracy and current rating.
- Voltage stability.
- Noise from DC-DC converter switching.
- IR drop across the power planes.
- Slow and fast current transients resulting from varying DSP processing loads.

Contents

1 Power Supply Accuracy and Current Rating

The power supply selected for the DSP core source must drive relatively large currents at a low voltage level. A DC-DC converter is more suitable for this purpose than a linear regulator. The power supply must be accurate within 1%. The maximum current rating should be at least 10% above than the DSP steady state current consumption in the worst working condition.

2 Main Input Voltage Stability

The main DC-DC voltage should meet the required DC-DC specification as listed in the MSC8144 data sheet.

3 DC-DC Converter Noise

The noise from a DC-DC converter transmitted to the load depends on various conditions, which can include the following:

- Load maximum current
- Switching frequency
- Output filter
- Input voltage.

There may be other factors in your design that can contribute to generated noise. A typical noise level is 15–25 mV.

4 IR Drop Across Power Planes

With low output voltage and high output current, the distribution voltage drops across the power planes have a profound effect on the output voltage level at the load. To minimize IR drops across the power planes, Freescale recommends that your design locates the power supply as closely as possible to the DSP device.

Board design directly affects the level of IR voltage drops. The PCB design should include solid power and ground planes. Using thick copper (one ounce and above) for the power layer also reduces impedance. Using multiple power/ground planes over different layers also decreases IR drops; however, using multiple vias to connect between the MSC8144 BGA package and signal connections decreases the effective plane surface and increases the IR drop at the device. Connect the power supply output to the power/ground planes using several power vias.

Although you can also use power supply sense pins to monitor voltage levels, there are two significant special cases for which their use is highly recommended:

- Multi-DSP system (DSP Farm)
- Designs in which the distance between the DSP and the power supply is greater than 3 inches.

For a single-device system, connect the sensor pins to isolated device power balls in the center of the package, as shown in see Figure 1. If the power planes support multiple devices, connect the sensor pins to the geometrical center of the group (See Figure 2)

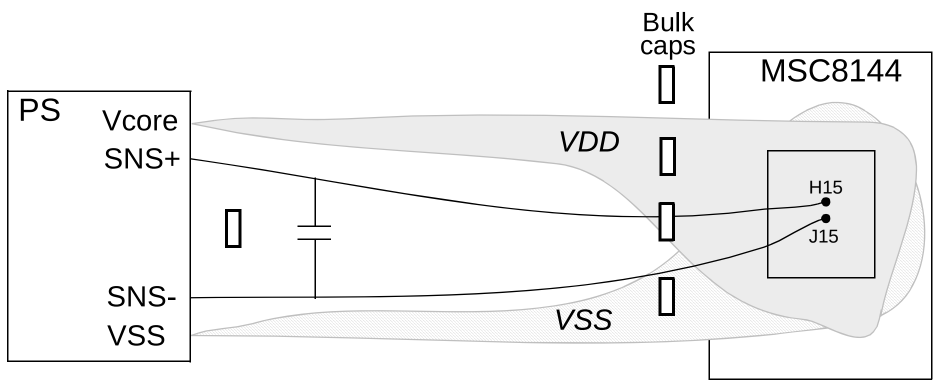

Figure 1. Remote Sensing for a Single Device

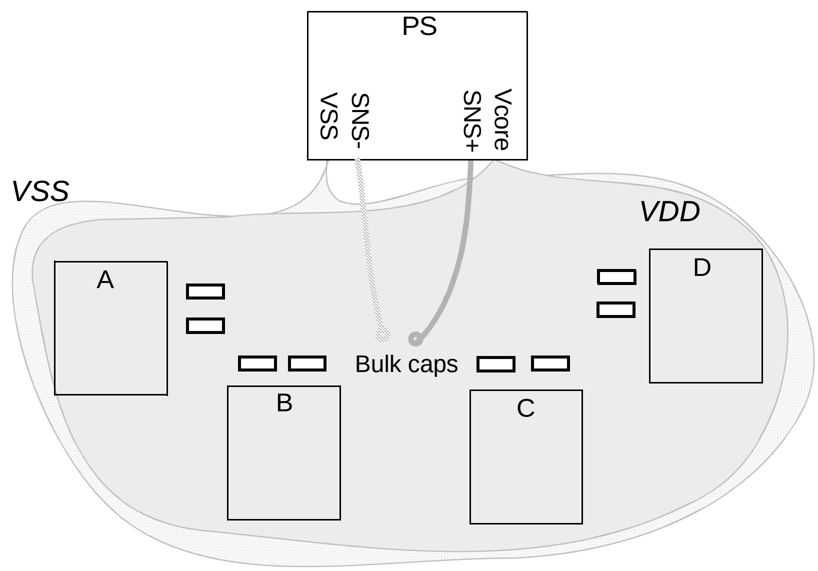

Figure 2. Remote Sensing for a DSP Farm

5 Slow and Fast Current Transients

Because of the variable loading of the DSP devices in terms of processing, both fast and slow transient noise spikes can be generated in a system. The power supply design should include filtering capacitors to minimize the effects of this generated noise on the core and on other devices in the system. There two types of capacitors used to minimize the effect of slow and fast transients:

- Bulk capacitors
- Bypass capacitors

5.1 Selecting Bulk Capacitors

Bulk capacitors work well for frequencies up to 500 KHz and decrease voltage spike levels creating by continuous slow switching operations. Most of the bulk capacitors are placed around the device on the board. They also serve to maintain the current flow if the load changes faster than power supply response time.

The minimum ESR of bulk parallel capacitor battery is calculated as follows:

ESR = Vmr/Itr,

where

Vmr is available voltage margin for working conditions

Itr is the change of current

Then,

Vmr = Vds - Vac - Vno,

where

Vds is taken from DSP data sheet

Vac is power supply voltage tolerance

Vno is noise level

There are two ways in order to calculate total volume of bulk capacitance, standard equation and SPICE modeling, described in the following two subsections.

5.1.1 Standard Equation

An approximate value is derived from the following equation:

$$C = 5\Delta I/(\Delta V / \Delta t),$$

where

ΔI = current transient

ΔV = allowable ripple

Δt = converter switching time

Using the MSC8144ADS as an example, the required bulk capacitance is:

$C = 5 \times 2.5\ A / (30\ mV / 2\ \mu S) = 833\ \mu F$

where

2.5 A is the current transient for a typical application

30 mV is the low core voltage tolerance given from the MSC8144 Data Sheet

2 µS is the switching time ofa Z-one DC-DC converter working at 500 KHz

5.1.2 SPICE Modeling

Output capacitance with total ESR can also be derived using a general SPICE model simulation and the MSC8144ADS. The SPICE model uses the basic configuration shown in Figure 3

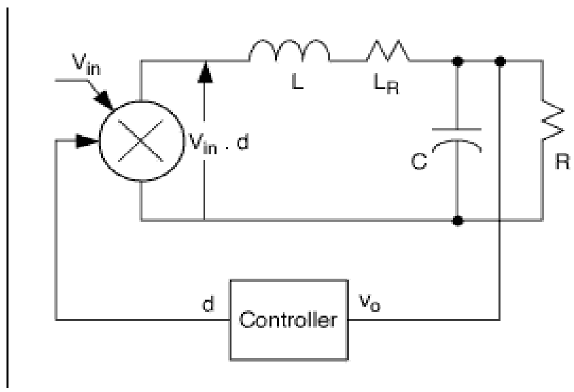

Figure 3. Model of Step-Down DC-DC Converter

The MSC8144ADS uses a Power-One Z-series Power supply with POLs controlled by a power monitor device. The dedicated MAXYZ Z-One Power System GUI allows you to perform transient simulation to determine the accurate value of required power filter system. For discussion purposes, assume that the continuous core current is 3.3 A and transient current adds up to 2.5 A. Insert the given numbers in the GUI menu as shown on Figure 4 and perform the simulation. The simulation generates the waveform shown in on Figure 5.

NOTE

Contact your local Freescale office or representative for information to use to derive estimated current values for specific applications and use that value with the SPICE model to calculate the correct capacitance value.

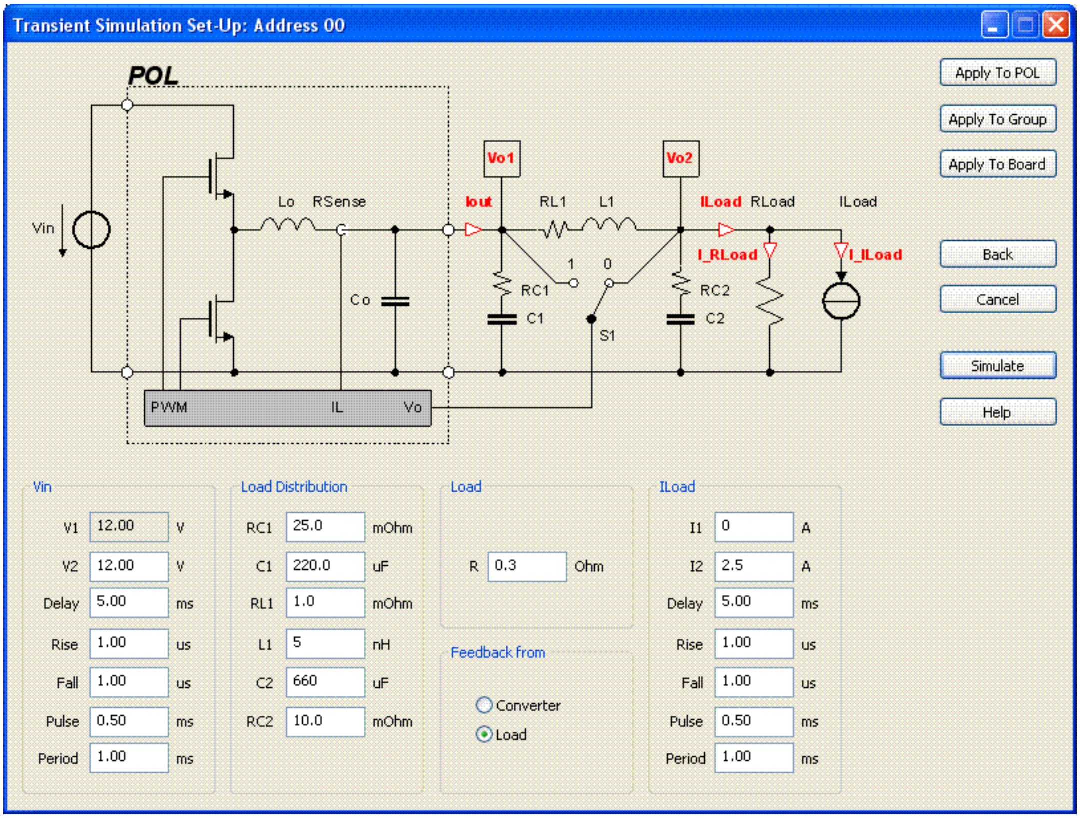

Figure 4. Power-One Converter Model

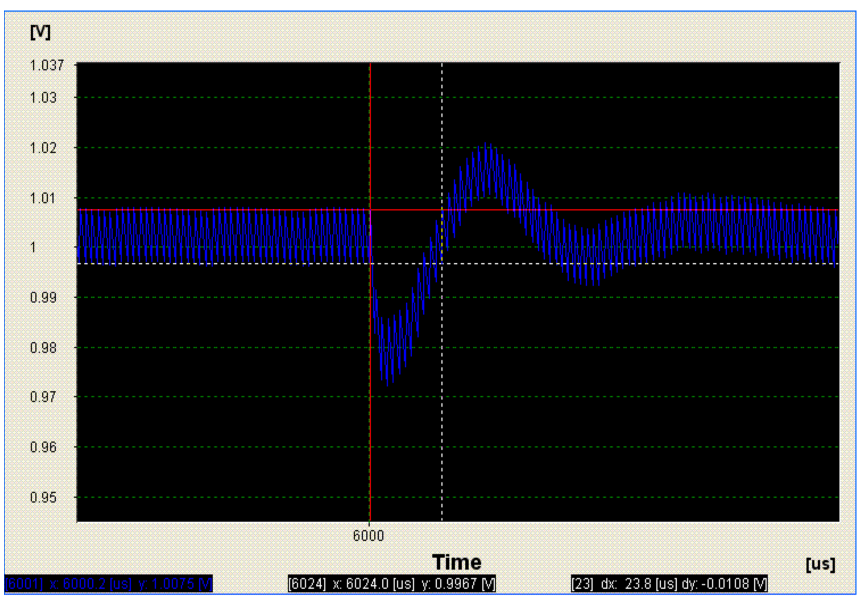

Figure 5. Simulation Output Waveform

The negative spike 28 mV (less 30 mV) meets the required operation conditions.

Figure 6 shows the recommended bulk capacitors placement relative to the power supply and the DSP device. Three 220 µF capacitors are placed close to the DSP and the fourth one is mounted on the side of the POL.

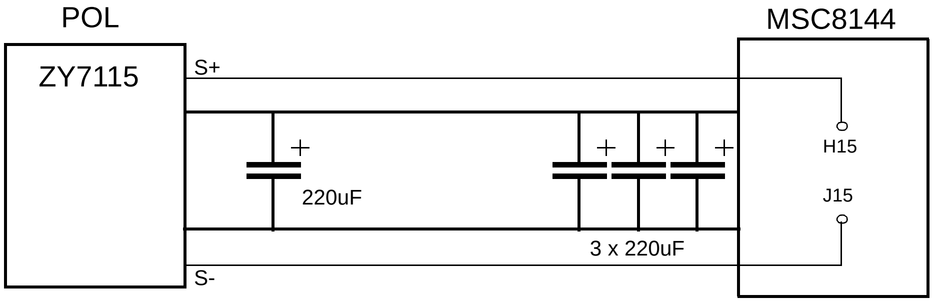

Figure 6. Bulk Capacitors Placement

NOTE

The results obtained from the SPICE simulation closely correlate with analytic approximation done by the equation.

5.2 Bypass Capacitors

The 0.01 µF and 0.1 µF bypass ceramic X7R capacitors with low ESR/ESL are ideal for filtering high frequency up to 50 MHz. The package pitch of 1 mm allows you to place capacitors adjacent to the power balls of the DSP. Figure 7 shows how the 0402 capacitors are placed on the PS (PCB print side) of the MSC8144ADS:

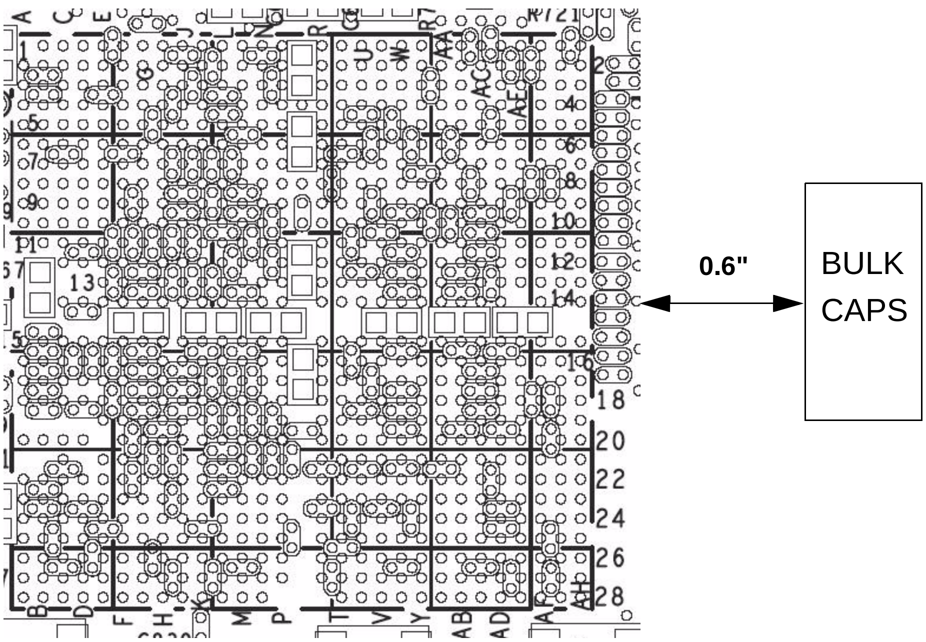

Figure 7. Bypass and Bulk Capacitors of MSC8144ADS

Small capacitors are arranged under the DSP device. The 0603 capacitors in the middle row and in middle column are 1 µF and 2.2 µF ceramic capacitors that perform better filtering over a several MHz frequency range. Table 1 summarizes the total number of bypass capacitors used in the ADS:

Table 1. Summary capacitors

Category	Big Low ESR Tantalum	Middle Ceramic	Small Ceramic
Value	220 µF, ESR=0.015 NEC NSP221M2.5D4TR	2.2 µF, CAPAX 0603X225K160ST, 1 µF, AVX 0603YC105KAT2	0.1 µF Cal-Chip GMC04X7R104K16NTLF 0.01 µF AVX 0402ZC103MAT2
Distance	1.0–1.2 inches	under device	under device
Quanity	1 + 3	2 + 4	19 + 18

6 Related Documentation

- *MSC8144 Data Sheet*
- *MSC8144E Data Sheet*
- *MSC8144EC Data Sheet*
- MAXYZ Z-One Power System GUI

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