Dual Power Supply Management for the TMS320VC549 Digital Signal Processor

APPLICATION BRIEF: SPRA280

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Dual Power Supply Management for the TMS320VC549 Digital Signal Processor

Abstract

As use of portable personal electronics such as cellular phones and pagers becomes more widespread, the demands made on these products become more stringent. Consumers want more features and longer battery life. As the heart of these devices, the digital signal processor (DSP) is also under the same pressure to demonstrate increased performance in terms of processing capability and reduced power consumption.

The TMS320VC549 meets this challenge with 100 MIPS performance while exhibiting greatly reduced power consumption over other standard CMOS DSPs. The speed improvement and power reduction have been achieved using an advanced CMOS process capable of full speed performance at low voltage. This combination makes the TMS320VC549 an ideal solution for portable and power-sensitive applications.

1. Power Supply Structure and Requirements of the TMS320VC549 DSP

1.1 Supply voltage structure and requirements

The TMS320VC549 is similar in design and architecture to the other members of the TMS320C54x family of DSPs. The device is most similar to a TMS320LC548 with additional memory. However, unlike the other devices in the TMS320C54x family, the TMS320VC549 utilizes a dual power supply scheme to achieve superior power performance.

Most of the TMS320C54x family operates at supply voltages of either 5, 3.3, or 3.0 V. The TMS320VC549 operates with a dual power supply of 3.3 and 2.5 V. The 2.5 V supply operates the internal logic on the device, including the CPU and all of the peripheral logic. Operation of the internal logic at 2.5 V provides a 44% reduction in power consumption over similar operation at 3.3 V. The 2.5 V power for the internal logic is supplied through the pins labeled CV_{dd} on the device pinout. For device pinouts and packaging information, refer to the TMS320C54x data sheet (literature number SPRS039).

The external interface pins continue to operate at 3.3 V providing direct connection to external low-voltage logic designs with no additional level-shifting circuitry required. The 3.3 V power for the external interface is supplied through the pins labeled DV_{dd} on the device pinout.

Both of the device power supplies are specified to a +/- 10% tolerance in voltage input. This implies an allowable voltage input of 2.25 - 2.75 V on the CV_{dd} supply and an allowable voltage input of 2.97 - 3.63 V on the DV_{dd} supply.

1.2 Current requirements

The current consumed by the TMS320VC549 is highly dependent on the device activity. The current use of the CV_{dd} supply is primarily due to the CPU activity. Current use of the peripherals is determined by the specific peripherals that are operating and the speed at which they are operating, but in general, this use is small compared to that of the CPU. The clock circuitry also contributes a small portion of the device current, and this current is constant regardless of the CPU or peripheral activity. CV_{dd} supplies current to all internal logic in the device including the CPU, clock circuitry, and all peripherals.

DV_{dd} supplies power to the external interface pins only. The current use of this supply is determined by the speed and number of external outputs that are switching in the application, and the external load capacitance on those outputs.

A complete examination of methods for estimating device power consumption is beyond the scope of this document, but is covered in detail in, Calculation of TMS320C54x Power Dissipation Application Report, literature number SPRA164. For the purposes of this document, some general current estimates will be used. The CV_{dd} supply will be considered first.

Using the information in the “Calculation of TMS320C54x Power Dissipation” Application Report, the highest expected current for the CPU on the TMS320VC549 is estimated at approximately 1.1 mA per MHz of CLKOUT. To provide a margin to allow for inclusion of the operation of various peripherals, a value of 1.5 mA per MHz of CLKOUT will be used to choose an appropriate voltage regulator. Although the average current use will most likely be much lower (approximately 0.45 mA per MHz of CLKOUT), the voltage regulator used must be able to drive the peak current value while maintaining the required voltage tolerance and without current limiting. Current limiting by the regulator could cause the DSP to fail to meet the required internal timing and consequently result in unpredictable behavior.

The current use of the CV_{dd} supply can now be estimated for the purpose of choosing a regulator. The speed the processor will be running during the application (frequency of CLKOUT) is multiplied by the 1.5 mA per MHz of CLKOUT current estimate. For example, if an application requires the TMS320VC549 to operate at 100 MHz, the maximum estimated current value is:

(1.5 mA per MHz of CLKOUT) * (100 MHz) = 150 mA

The minimum current used by the processor is also a consideration in regulator choice. The TMS320VC549 has three low power modes (IDLE1, IDLE2, IDLE3) which greatly reduce power consumption by disabling part or all of the internal functions of the processor. IDLE 3 mode exhibits the minimum current use by disabling the CPU, most of the peripherals, and the PLL clock generation circuitry. Under the appropriate conditions, the TMS320VC549 can maintain a power-down mode with less than 1 μA of current use. For more information on this state, refer to the Calculation of TMS320C54x Power Dissipation Application Report.

The current used by the DV_{dd} supply is not only dependent on the device activity, but also the hardware environment. The current is proportional to the number of external pins switching. As the frequency of external activity increases, so does the current. The current is also proportional to the external load capacitance the outputs are required to drive. As the load increases, the current supplied by the DV_{dd} supply increases.

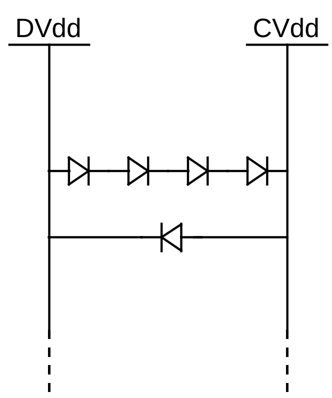
Estimating the current for the DV_{dd} supply is therefore much more difficult because of the dependence on the application environment. To estimate this current for a known application, refer to the Calculation of TMS320C54x Power Dissipation Application Report. If the processor activity is confined to internal tasks (i.e. no external device pins are changing state including CLKOUT and control pins), the minimum current on the DV_{dd} supply can be estimated to be zero.

1.3 Power supply sequencing and differences

Since there are two supplies, an additional issue to consider in a power supply scheme for the TMS320VC549, is power supply sequencing. Ideally, the two supplies on the processor should be brought up simultaneously. However, in some cases this is not possible. If not, bring up the DV_{dd} supply first, then bring up the CV_{dd} supply. Make sure that the DV_{dd} does not exceed the CV_{dd} supply by more than 2V.

The reason for this sequence lies in the electrostatic discharge protection circuitry on the TMS320VC549. The internal structure of this circuitry is comparable to that shown in Figure 1. From this diagram, it is clear that DV_{dd} must not exceed CV_{dd} by more than four diode voltage drops (approximately 2 V) and CV_{dd} may not exceed DV_{dd} by more than one diode voltage drop (approximately 0.5 V) as excessive current could flow and damage the device.

Figure 1. TMS320VC549 Internal Protection Circuitry



1.4 Voltage Regulator Considerations

Although voltage regulators are relatively simple devices from a design point of view, there are several factors to consider when choosing a voltage regulator.

Load current is the amount of current that the regulator can supply to the load while maintaining voltage regulation and staying within its specified temperature range. Many regulators have output current limiting systems which detect either excessive output current and/or excessive internal temperature, and limit or shut-off the output current supply until normal conditions have been restored.

Dropout voltage is the minimum voltage difference between the regulator input and the regulator output at which the device will still maintain regulation of the specified voltage. Essentially, this aspect of the regulator limits the minimum allowable input voltage to the regulator. This may be of special concern in battery powered systems where the input voltage decreases over time. Most commonly available voltage regulators have dropout voltages above 2.5 V. In some applications (i.e. Case 2), these dropout voltages are too high and specially designed low-dropout regulators should be considered.

Quiescent current is the current required by the regulator to maintain output voltage regulation. Some regulators have a ground terminal and can maintain the quiescent current with no output load current present. Other regulators, in the interest of improved power efficiency, route the bias current for the regulator through the output to the load. This improves power efficiency, but imposes a requirement that the load current be at least the amount necessary to bias the regulator appropriately. Consequently, this type of regulator has a minimum output load current requirement.

To choose a regulator for the TMS320VC549, both the maximum expected current and the minimum expected current should be considered. The regulator should be chosen such that, at the maximum output current, it is still capable of supplying the current while maintaining its voltage regulation and temperature limits. The regulator should never limit the output current during expected operating conditions or unpredictable behavior of the DSP may result.

The minimum current used by the DSP should also be considered. There are conditions where the DSP can consume at very low current levels (e.g. IDLE 3 mode). If the regulator requires a minimum output current, it should be compatible with the expected current use of the DSP. If the output current falls too low, the regulator may lose regulation and behave unpredictably. Consequently, a regulator should be chosen that is tolerant of the minimum load current expected, or the load should be controlled so that it never falls below the minimum requirement of the regulator.

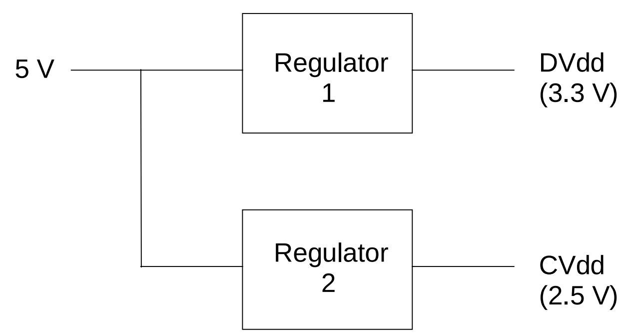
2. Supply Voltage Generation for the TMS320VC549

The choice for a power supply scheme for the TMS320VC549 is primarily based on what supply voltages are available in the application. Since most digital systems are currently operating on 5 V or 3.3 V, these two cases are presented.

2.1 Case1: Voltage generation from a 5 V supply

Figure 2 shows a scheme for generating 3.3 V and 2.5 V supplies from an original 5 V supply. In this case, regulator 1 supplies the 3.3 V supply of the TMS320 VC549 and regulator 2 supplies the 2.5 V supply. Regulator 1 will experience a voltage drop between input and output of 1.7 V during normal operation. Regulator 2 will experience a voltage drop of 2.5 V during normal operation. The regulators should be chosen such that the expected voltage drop across the regulator during normal operation exceeds the dropout voltage rating for the regulator. There are a wide variety of voltage regulators currently available which meet these requirements.

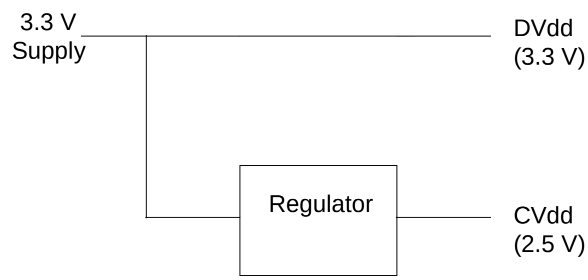
Figure 2. Generation of TMS320VC549 Split Power Supplies From a Single 5 V Supply



2.2 Case 2: Voltage generation from a 3.3 V supply

Figure 3 shows a scheme for generating a 2.5 V supply from an existing 3.3 V supply. In this case, the regulator will experience a voltage drop between input and output of 0.8 V during normal operation. This dropout voltage is below the limit of many commonly available regulators and will require a low-dropout regulator.

Figure 3. Generation of TMS320VC549 Split Power Supplies From a Single 3.3 V Supply



3. A Solution Using the TI TPS71xx and TPS72xx Series of Voltage Regulators

Texas Instruments provides a series of low dropout voltage regulators with excellent characteristics that perform as the regulators shown in Figures 2 and 3. These regulators exhibit extremely low dropout voltage and maintain regulation even when the load current drops to zero. They also perform well as a solution for low-power applications due to low quiescent current, in the range of 220 µA with a 3.3 V input. The output load current rating is 500 mA for the TPS71xx series and 250 mA for the TPS72xx series. For more detailed information on this series of regulators, refer to the data sheets (literature number SLVS092 for the TPS71xx, and SLVS102 for the TPS72xx series), or contact your TI field sales representative. These data sheets can be ordered from the TI Literature Response Center at (800) 477-8924, or downloaded from TI's web site at www.ti.com.

The regulators in this series are available in fixed-voltage and adjustable voltage versions. The TPS7133 is a fixed 3.3 V output. The TPS7101 is an adjustable output, programmable from 1.2 V to 9.75 V. Two 3.3 V solutions are presented. One uses the fixed output voltage TPS7133 and the other uses the adjustable output voltage TPS7101 programmed to 3.3 V. The TPS7133 solution is shown in Figure 4. The TPS7101 version is shown in Figure 5. In each of the cases shown, the TPS72xx series regulator can be substituted for the TPS71xx if higher load current is not required.

Figure 4. A 3.3 V Power Supply Solution Using the TPS7133 Regulator

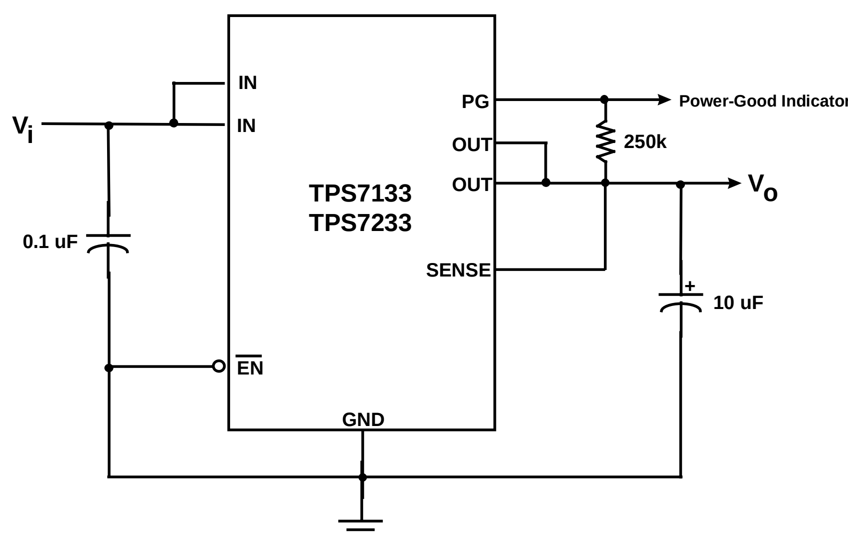
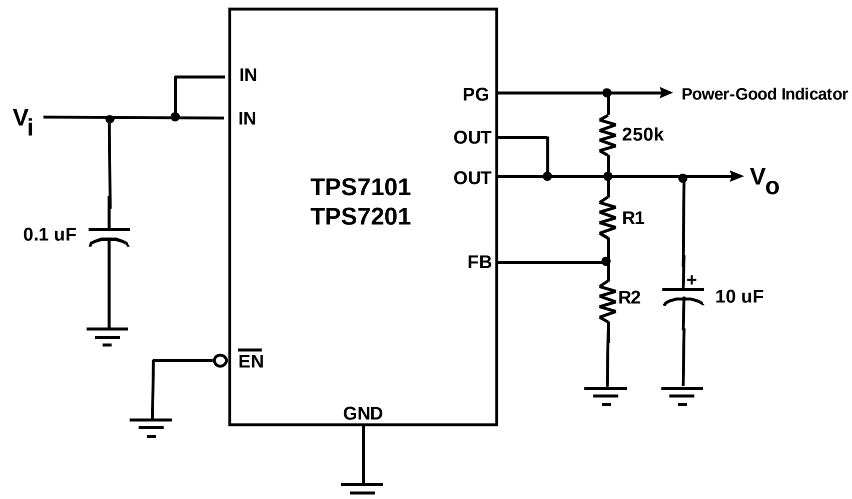


Figure 5. A Power Supply Solution Using the TPS7101 Regulator



The circuit shown in Figure 5 can be configured for 3.3 V or 2.5 V based on the choice of the values of resistors R1 and R2. The following resistor values are recommended for proper operation while minimizing power dissipation in the sensing circuit. A 1.8 V solution is also shown which will optimize performance for future devices which operate with 1.8 V on CV_{dd}.

Table 1. Resistor Values

Output Voltage (V)	R1 (ohms)	R2 (ohms)
3.3	309 k	169 k
2.5	191 k	169 k
1.8	87 k	169 k

The resistor values given are 1% tolerance. Other component values may be chosen as necessary. Some external component requirements may vary based on the application hardware environment. Consult the appropriate data sheet for information on requirements of the external components.

4. Conclusion

Issues related to the implementation of dual power supplies on the TMS320VC549 have been presented, including the considerations necessary to appropriately choose voltage regulators that provide power to the device. In addition, solutions utilizing the TPS71xx / TPS72xx series of low-dropout voltage regulators were shown.