Power supply solutions for TI DSPs using synchronous buck converters

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Introduction

This article describes simple power solutions for TI's TMS320C6000 and TMS320VC54xx DSP applications using synchronous buck converter controllers such as the TPS56100, TPS5210, TPS56xx, and TPS5602. DSP power solutions from a single-input-only system (5-V or 12-V), a dual-input system (5-V and 12-V), and a wide-input voltage system (4.5-V ~ 25-V) are presented.

Review of DSP power requirements and synchronous buck converter controllers

The TI DSP families ('C6000 and 'C54xx) require separate core and I/O power. Table 1 summarizes the voltage supply for the current 'C6000 and 'C54xx families.

TI DSPs do not require specific power sequencing between the core supply and the I/O supply; however, systems should be designed to insure that neither supply is powered up for extended periods of time if the other supply is below the proper operating voltage. Excessive exposure to these conditions can adversely affect the long-term reliability of the device. System-level concerns such as bus contention may require supply sequencing to be implemented. In this case, the core supply should be powered up at the same time as, or prior to (and powered down after), the I/O buffers.

TI's synchronous buck converter controllers (TPS56100, TPS5210, TPS56xx, and TPS5602) are specifically designed to provide excellent transient response and high efficiency for the microprocessor power applications such as the 'C6000 and 'C54xx families from TI, as well as similar digital loads. In addition, the hysteresis control method is used so that power-supply designers do not have to worry about the stability and compensation issues. Table 2 summarizes the controller characteristics.

Table 1. Summary of DSP 'C6000 and 'VC54xx power requirements

TI DSP	CORE VOLTAGE (V)	I/O VOLTAGE (V)
TMS320C6201/'C6202/'C6211	1.8	3.3
TMS320C6202B/'C6203/'C6204/'C6205	1.5	3.3
TMS320C6701/'C6711	1.8	3.3
TMS320VC5402/'VC5409/'VC5420/'VC5421	1.8	3.3
TMS320VC549/'VC5410	2.5	3.3
TMS320VC5416/'VC5441	1.5	3.3

Solution 1—single-input voltage application (V_{in} = 5 V)

The TPS56100, a synchronous buck switch-mode power-supply controller, provides an accurate programmable supply voltage suitable for 5-V input-only microprocessor power applications. The reference voltage, ranging from 1.3 V to 2.6 V, is determined by the voltage programming (VP) pins. The output voltage can be set equal to the reference voltage using VP, or it can be extended to some multiple of the reference voltage using the sampling resistors (R2, R3) (see Figure 1). The TPS56100 also includes an inhibit input to control power sequencing and under-voltage lockout, thereby insuring the 5-V supply is within limits before the controller starts.

Table 2. Summary of the TI synchronous buck converter controller characteristics

	V_{in} RANGE (POWER STAGE) (V)	V_{CC} RANGE (CONTROLLER) (V)	V_{out} RANGE (POWER STAGE) (V)	I_{out}* (POWER STAGE) (A)	DRIVER CURRENT (CONTROLLER) (A)	OTHERS
TPS56100	5	5	1.3 to 2.6	7	2	1 channel
TPS5210	4.5 ~ 12	12	1.3 to 3.5	8	2	1 channel
TPS56xx	5	12	1.5, 1.8, 2.5, or 3.3	8	2	1 channel
TPS5602	4.5 ~ 25	4.5 ~ 25	Adjustable	4/channel	1.2 at V_O = 3 V	2 channels

*The current capability can be extended in multi-phase configuration or if the switching devices are added in parallel; see Table 2 in TI TPS56100/5210 datasheets.

Figure 1 shows the typical application circuit using the TPS56100, which features an accurate programmable step-down DC-DC converter. The VP pins and the two external resistors (R2, R3) determine a programmable output voltage from 1.3 V to approximately 5 V. The output voltage, V_O, is set with the following equation:

$$V_o = \left(1 + \frac{R2}{R3}\right) V_{ref} \qquad \textbf{(1)}$$

Figures 2 and 3 show power solutions using the TPS56100, suitable for 5-V-only systems. The application circuit for 1.5-V core and 3.3-V I/O supply voltage is identical with the figures except for the core voltage supply (1.5 V) and SVS. To avoid bus contention issues within a DSP system, the recommended start-up sequencing is met by using PWRGD (power good signal) pins as shown in the figures. The PWRGD connected to the Enable pin of the other power supply provides the start-up sequencing (core voltage first, then peripheral voltage). After approximately 10 ms —set by C5, R4, and R5 (see Figure 1)— the voltage on the PWRGD pin goes high, and the other TPS56100 is brought up.

The Schottky diode D1 provides a measure of protection during the power-down sequence and during other periods when the DV_{DD} supply is below the CV_{DD} supply by limiting the CV_{DD} - DV_{DD} voltage to the forward drop of D1. If CV_{DD} fails, the PWRGD pin of the power supply shuts down the other supply.

Figure 1. A 5-V input-only application circuit using the TPS56100 (7-A output)

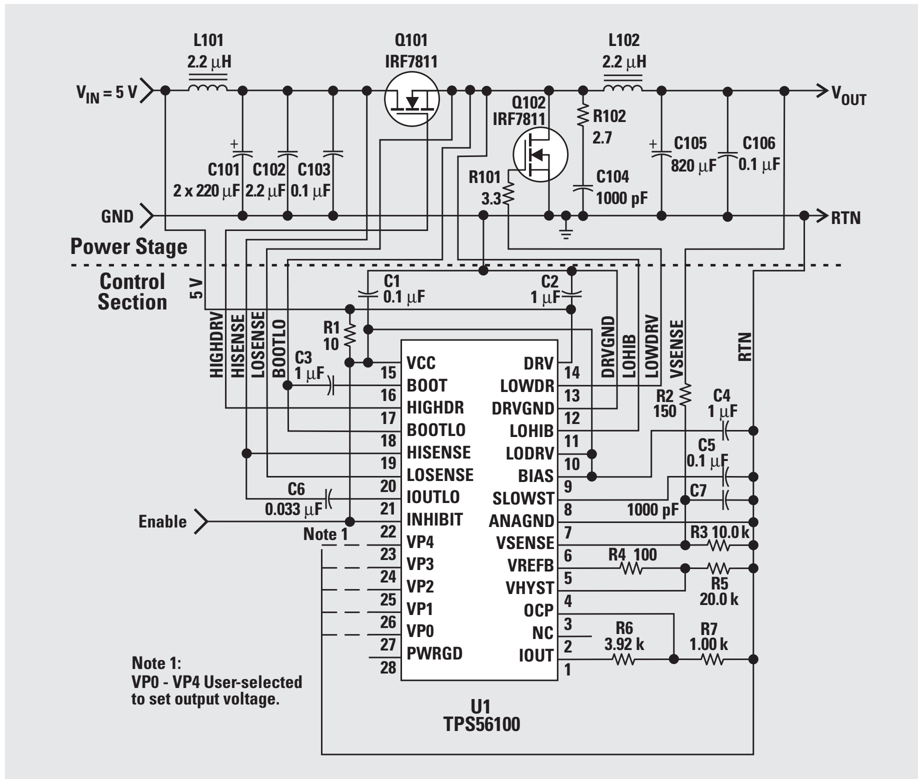

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Figure 2. TMS320C6000/’VC5420/’VC5409/ ’VC5402 power-supply solution using TPS56100 for a 5-V input-only system

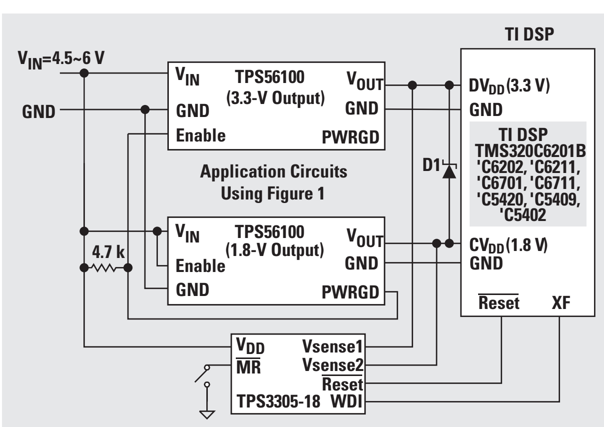

Figure 3. TMS320VC549/’VC5410 power-supply solution using TPS56100 for a 5-V input-only system

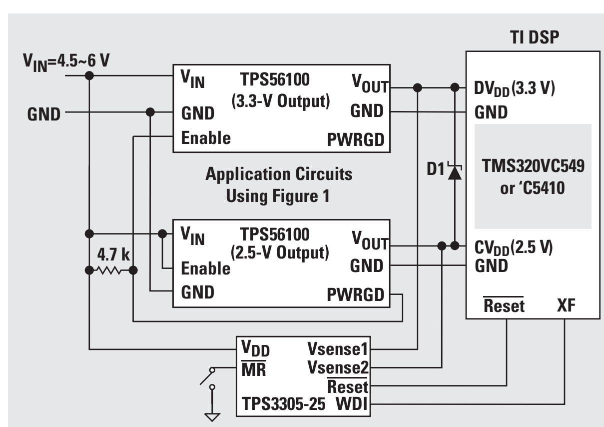

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Table 3. Summary of setting values for TPS56100 1.5-/1.8-/2.5-/3.3-V outputs

OUTPUT VOLTAGE (V)	R2 (Ω)	R3 (Ω)	C7 (pF)	VP TERMINALS (0 = GND, 1 = FLOATING OR PULL-UP TO 5 V)					V_{ref}
				VP4	VP3	VP2	VP1	VP0	(V_{dc})
3.3	1K	1K	100	0	1	0	0	0	1.65
2.5	100	20K	1000	1	1	0	1	0	2.50
1.8	100	20K	1000	0	0	1	0	1	1.80
1.5	100	20K	1000	0	1	0	1	1	1.50

Table 3 shows the setting values of TPS56100 to generate the output voltages 1.5 V, 1.8 V, 2.5 V, or 3.3 V. To obtain the 3.3-V output, set the reference voltage to 1.65 V and replace R2 and R3 with 1-kΩ resistors. For the 1.5-V, 1.8-V, and 2.5-V output voltages, the reference voltage represents the output voltage.

Two EVMs (evaluation modules)—SLVP128 (7-A output) and SLVP133 (3-A output)—are available to provide a convenient method for evaluating the performance of the TPS56100. A completed and tested power supply is included in each EVM.

Solution 2—single-input voltage application (V_{in} = 12 V)

The TPS5210 is suitable for single 12-V input-only system applications. The reference voltage, ranging from 1.3 V to 3.5 V, is determined by the voltage identification code (VID) pins. The output voltage can be set equal to the reference voltage using VID or can be extended to some multiple of the reference voltage using the external sampling resistors (R2, R3). The TPS5210 also includes an inhibit input to control power sequencing.

Figure 4 shows the typical application schematic using the TPS5210, which features a fast step-down DC-DC converter.

The VID pins and the two external resistors (R2, R3) determine a programmable output voltage from 1.3 V to approximately input supply voltage. The output voltage between 1.3 V and 3.5 V can be easily set by shorting the correct VID inputs to ground. Values above the maximum reference voltage (3.5 V) can be achieved by setting the reference voltage to any convenient voltage within its range and selecting values for R2 and R3 to give the correct output.

Figure 4. A 12-V input-only application circuit using the TPS5210 (8-A output)

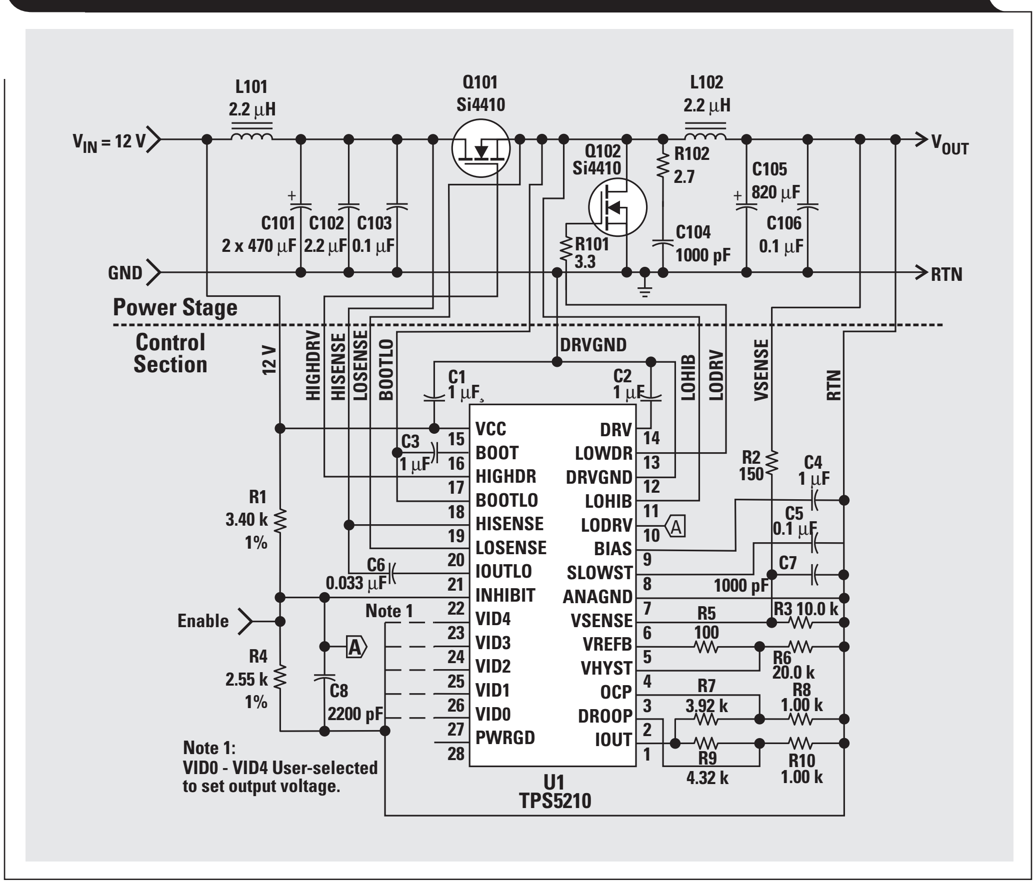

Table 4. Summary of setting values for TPS5210 1.5-/1.8-/2.5-/3.3-V outputs

OUTPUT VOLTAGE	VID TERMINALS (0 = GND, 1 = FLOATING OR PULL-UP TO 5 V)					V_{ref}
(V)	VID4	VID3	VID2	VID1	VID0	(V_{dc})
3.3	1	0	0	1	0	3.30
2.5	1	1	0	1	0	2.50
1.8	0	0	1	0	1	1.80
1.5	0	1	0	1	1	1.50

The output voltage is obtained with the following equation:

$$V_o = \left(1 + \frac{R2}{R3}\right) V_{ref} \qquad (2)$$

R2 and R3 can also be used to make small adjustments to the output voltage within the reference voltage range and/or to adjust for load-current active droop compensation. If there is no need to adjust the output voltage, R3 can be eliminated.

Table 4 shows the setting values of TPS5210 to generate the output voltages 1.5 V, 1.8 V, 2.5 V, or 3.3 V. The reference voltage represents the output voltage.

The power solutions for TMS320C6000 and TMS320VC54xx using TPS5210 are shown in Figures 5 and 6. As described in the previous section, the cross-connection between PWRGD (power good signal) and Enable provides the start-up sequencing. The application circuit for 1.5-V core and 3.3-V I/O supply voltage is identical with Figures 5 and 6 except for the core voltage supply (1.5 V) and SVS.

The two power supplies should be placed close to the DSP to minimize the trace resistance and inductance and to minimize the ground loop current between the two output grounds. This ground loop current can generate radiated EMI noise that can adversely affect any circuitry within the loop. The ground connection must be made directly on the DSP to help minimize the problem.

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Figure 5. TMS320C6000/’VC5420/’VC5409/’VC5402 power-supply solution using TPS5210 for a 12-V input-only system

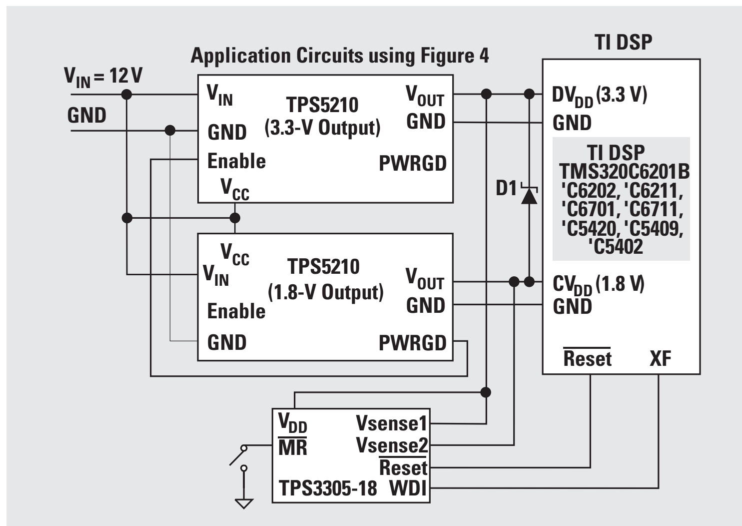

Figure 6. TMS320VC549/’VC5410 power-supply solution using TPS5210 for a 12-V input-only system

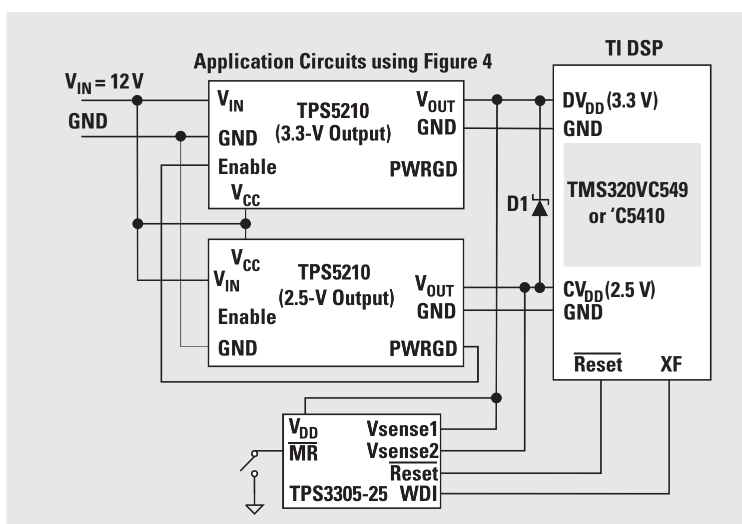

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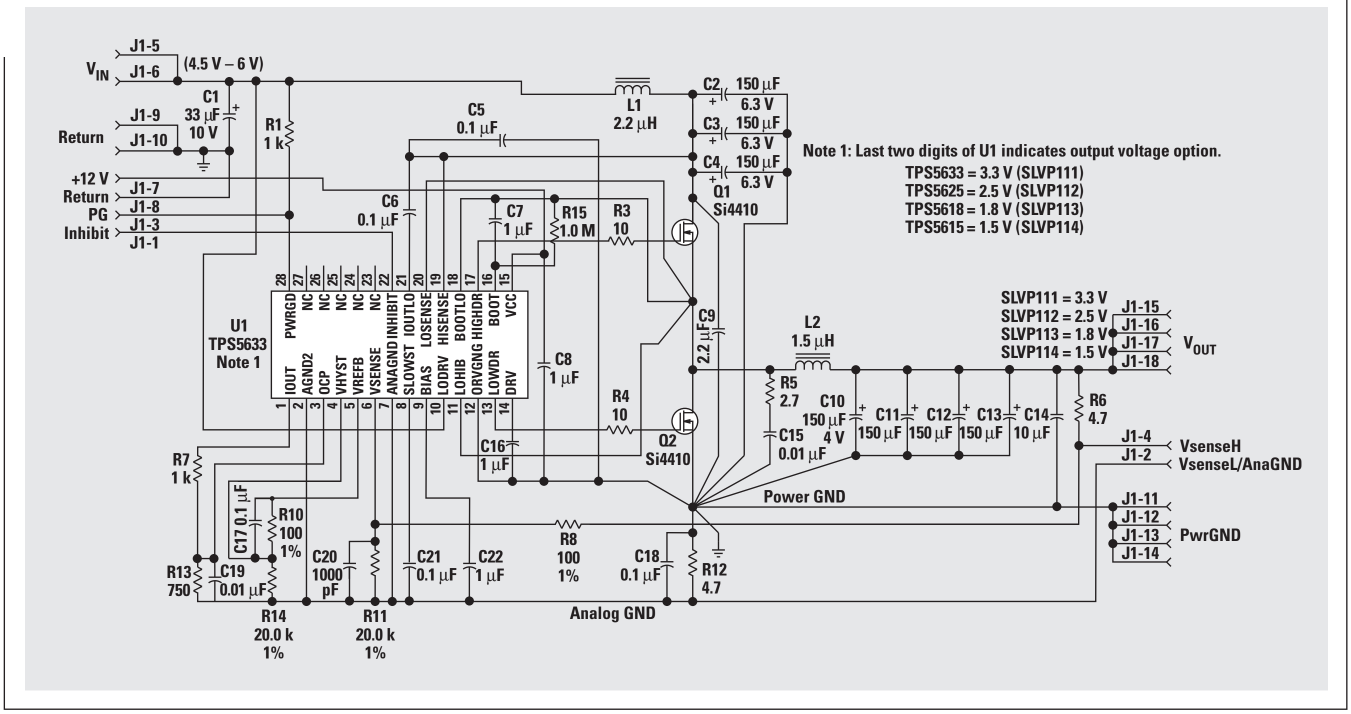
Figure 7. A dual-input application circuit using the TPS56xx (8-A output)



Solution 3—dual-input voltage application (V_{in} = 5 V and 12 V)

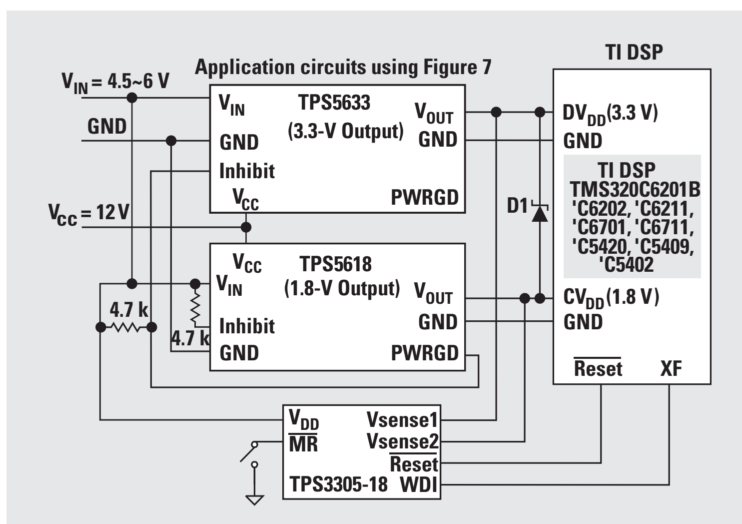
The TPS56xx, a synchronous buck switch-mode power-supply controller, is useful in applications with dual-input voltages and wide DC load ranges, such as multiple-DSP applications. Synchronous buck converters using the TPS56xx feature fixed output voltages of 3.3 V, 2.5 V, 1.8 V, or 1.5 V, providing an elegant power-supply solution for rapidly transitioning DSP loads, fast memory, and similar processors.

A hysteretic controller with user-selectable hysteresis is used to dramatically reduce overshoot and undershoot caused by load transients. The inhibit pin can be used to control power sequencing. Inhibit and undervoltage lockout assures that the 12-V supply voltage and system supply voltage (5 V) are within proper operating limits before the controller starts.

Figure 7 shows the typical application circuit using the TPS5633, which features an accurate 3.3-V output. The optional output voltages (1.5 V, 1.8 V, or 2.5 V) are obtained by replacing controller U_1 with TPS5615, TPS5618, or TPS5625 devices, since the power stage circuitry is identical.

Power solutions using the TPS56xx for TI's DSP are shown in Figures 8 and 9. The application circuit for 1.5-V core and 3.3-V I/O supply voltage can be implemented as described in previous sections.

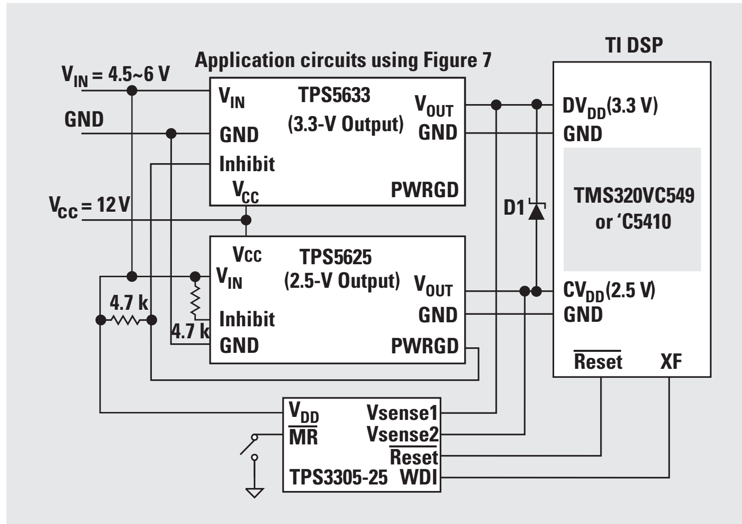
Figure 8. TMS320C6000/'VC5420/'VC5409/'VC5402 power-supply solution using the TPS5618 and TPS5633 for a dual-input system



The PWRGD connected to the inhibit pin of the other power supply provides the start-up sequencing (core voltage first, then peripheral voltage). After approximately 10 ms—set by C21, R10, and R14 (Figure 7)—the voltage on the PWRGD pin goes high, and the other TPS56xx is brought up.

Four EVMs—the SLVP111 (3.3 V), SLVP112 (2.5 V), SLVP113 (1.8 V), and SLVP114 (1.5 V) —are available to provide a convenient method for evaluating the performance of the TPS56xx. A completed and tested power supply is included in the EVM.

Figure 9. TMS320VC549/'VC5410 power-supply solution using the TPS5625 and TPS5633 for a dual-input system (5 V and 12 V)



Solution 4—single wide-input voltage application (V_{in} = 4.5 ~ 25 V)

TI TPS5602, a dual-channel synchronous buck switch-mode power-supply controller, features very fast feedback control and dual channels and is designed specifically for DSP applications that require single wide-input applications. The up and down power sequencing can be easily achieved by setting the standby pins, since both channels are independent. The wide-input voltage and adjustable output voltage make the TPS5602 suitable for many applications.

Figure 10 shows a typical circuit design using the TPS5602 that features a dual-channel synchronous buck converter (1.8-V and 3.3-V outputs). The two output voltages are independent and can be adjustable (1.2-V to approximately input voltage) by using the sampling resistors such as R1,

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Figure 10. A single wide-input application circuit using the TPS5602 (8-A output)

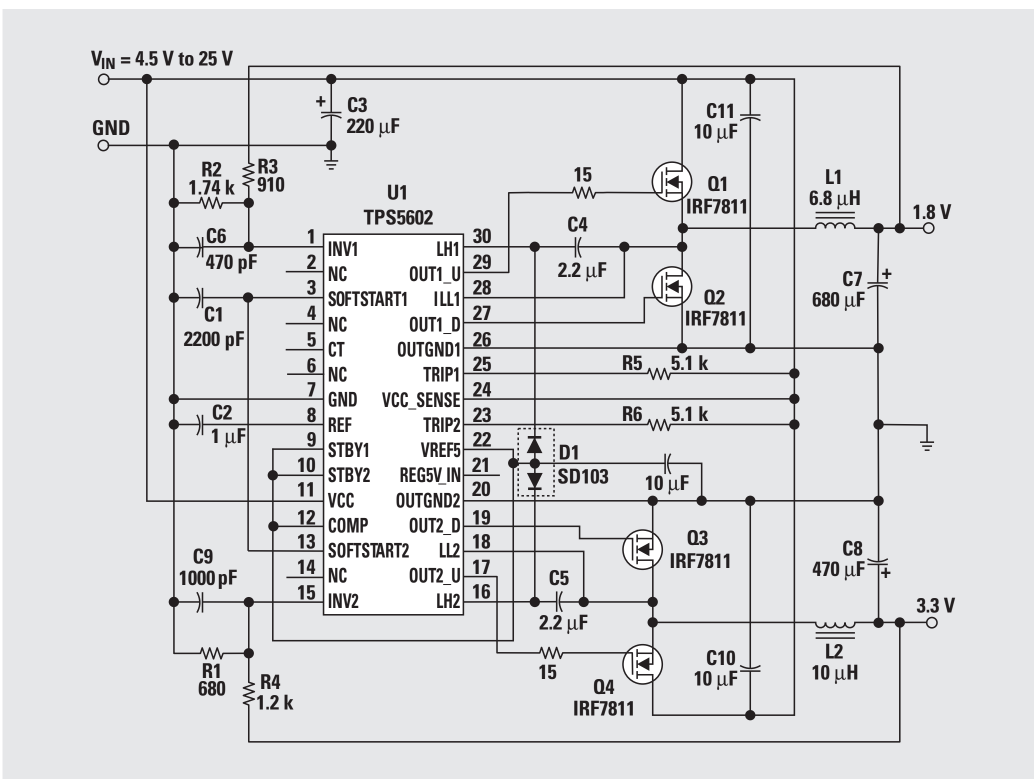

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Figure 11. Fast load transient response

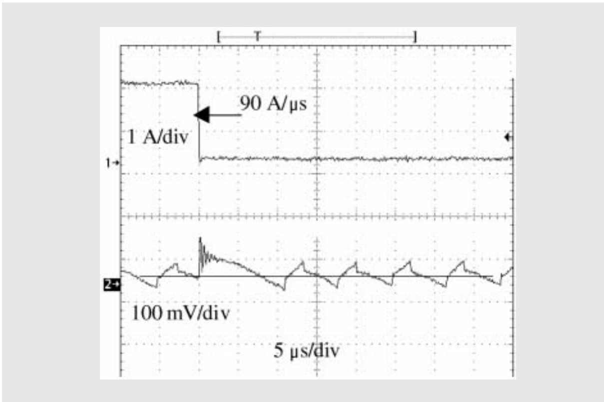


Figure 12. Efficiency of 3.3-V output

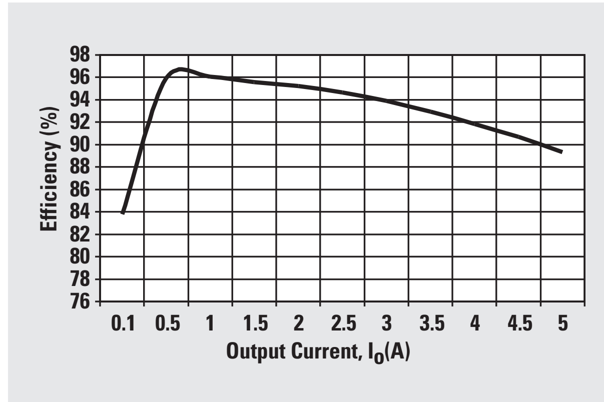
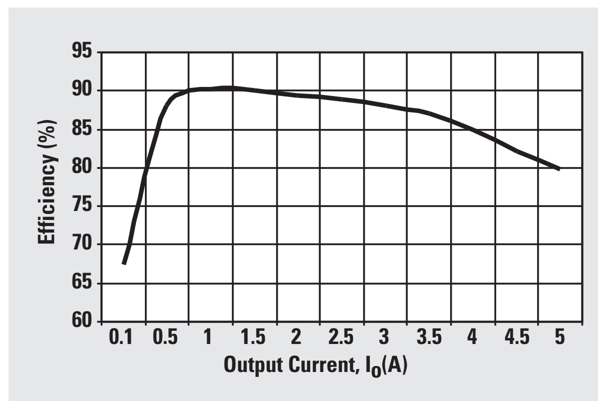


Table 5. Summary of setting values for TPS5602 1.5-/1.8-/2.5-/3.3-V outputs

OUTPUT VOLTAGE (V)	R2 (or R1) (Ω)	R3 (or R4) (Ω)
3.3	680	1.2K
2.5	1K	1.1K
1.8	1.74K	910
1.5	10K	2.67K

Figure 13. Efficiency of 1.8-V output



R2, R3, and R4. The output voltages, OUT1 and OUT2, are set with the following equations, where the reference voltage is 1.185 volts:

$$V_{OUT1} = \left(1 + \frac{R3}{R2}\right) V_{ref} \tag{3}$$

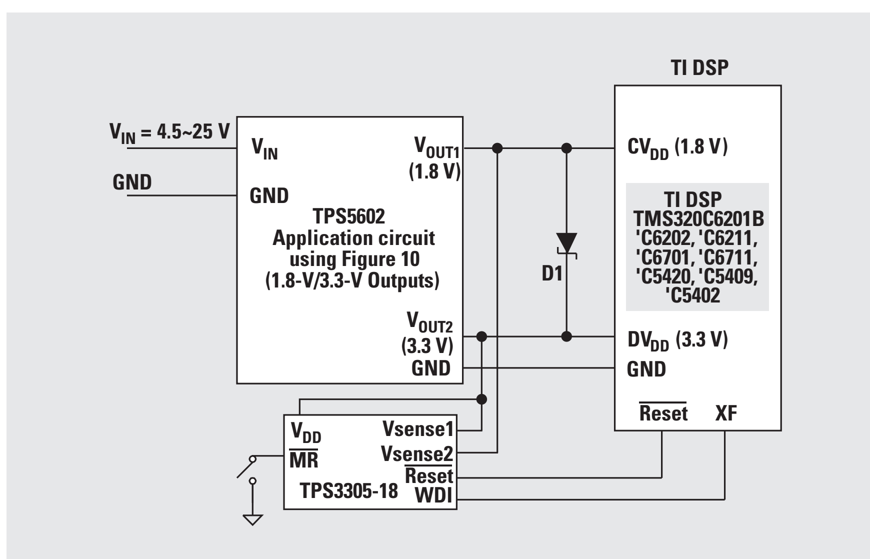
$$V_{OUT2} = \left(1 + \frac{R4}{R1}\right) V_{ref} \tag{4}$$

Figure 11 shows the TPS5602's transient response. The response is less than 2 microseconds after a load is applied. Conventional PWM buck converters exhibit approximately 100 microseconds of response. Figures 12 and 13 show the efficiency of the two controllers over load up to 5 A. Efficiency can be improved by choosing lower on-resistance MOSFET.

Table 5 shows the setting values of TPS5602 to generate the output voltages 1.5 V, 1.8 V, 2.5 V, or 3.3 V.

The power solutions for TMS320C6000 and TMS320VC54xx using TPS5602 are shown in Figures 14 and 15. The application circuit for 1.5-V core and 3.3-V I/O supply voltage can be implemented as described in previous sections.

Figure 14. TMS320C6000/'VC5420/'VC5409/'VC5402 power-supply solution using TPS5602 for a single wide-input system (4.5 V ~ 25 V)



By using the SOFTSTART1 and SOFTSTART2 pins in Figure 10, the start-up sequencing (core voltage first, then peripheral voltage) can be easily achieved. The SOFTSTART timing can be adjusted by selecting the SOFTSTART capacitor value such as C1 and C12 shown in Figure 10. The equation is

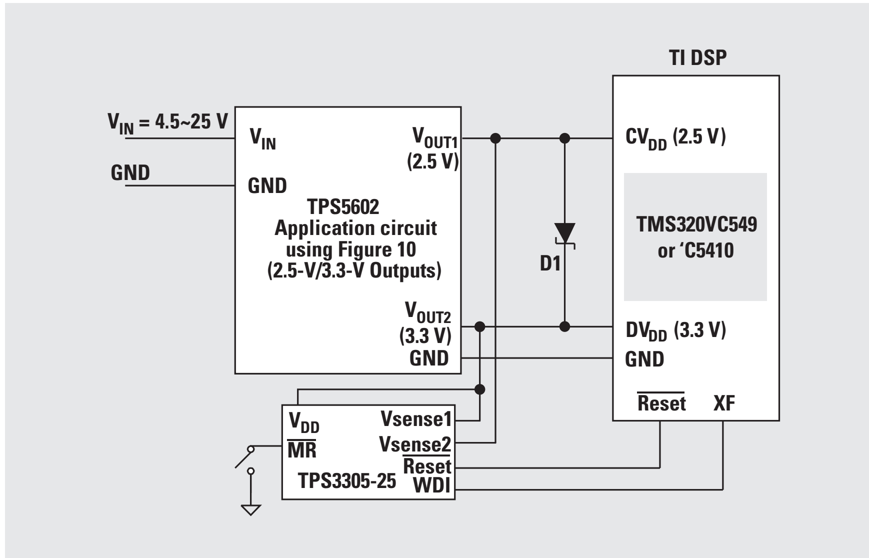
$$C_{soft}(\mu F) = 2 \times T_{soft}(ms), \quad (5)$$

where C_{soft} is the SOFTSTART capacitance and T_{soft} is the start-up time.

For example, to set the start-up time T_{soft} = 5 ms, the capacitance value of C_{soft} = 0.01 µF is needed.

In addition, the TPS5602 has two external pins (STBY1, STBY2) that can be used alternatively for power-up sequencing.

Figure 15. TMS320VC549/'VC5410 power-supply solution using the TPS5602 for a single wide-input system (4.5 V ~ 25 V)



References

For more information related to this article, visit the TI Web site at www.ti.com/ and look for the following materials by entering the TI literature number into the quick-search box.

Document Title	TI Lit. #
1. TPS3305 Application Report	SLVA056
2. TPS5210 Data Sheet	SLVS171
3. TPS5210 User's Guide	SLVU010, SLVU011
4. TPS56xx Data Sheet	SLVS177a
5. TPS56xx User's Guide	SLVU007, SLVU013
6. TPS5602 Data Sheet	SLVS217
7. TPS56100 Data Sheet	SLVS201a
8. TPS56100 User's Guide	SLVU018

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