Powering the TMS320VC5402 Using the TPS60100, TPS76918, and the TPS3305-18

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ABSTRACT

This report analyzes a low-cost, low-power supply design utilizing the TPS60100 dc-to-dc converter, the TPS76918 series regulator, and the TPS3305–18 power-supply supervisor to power DSP applications.

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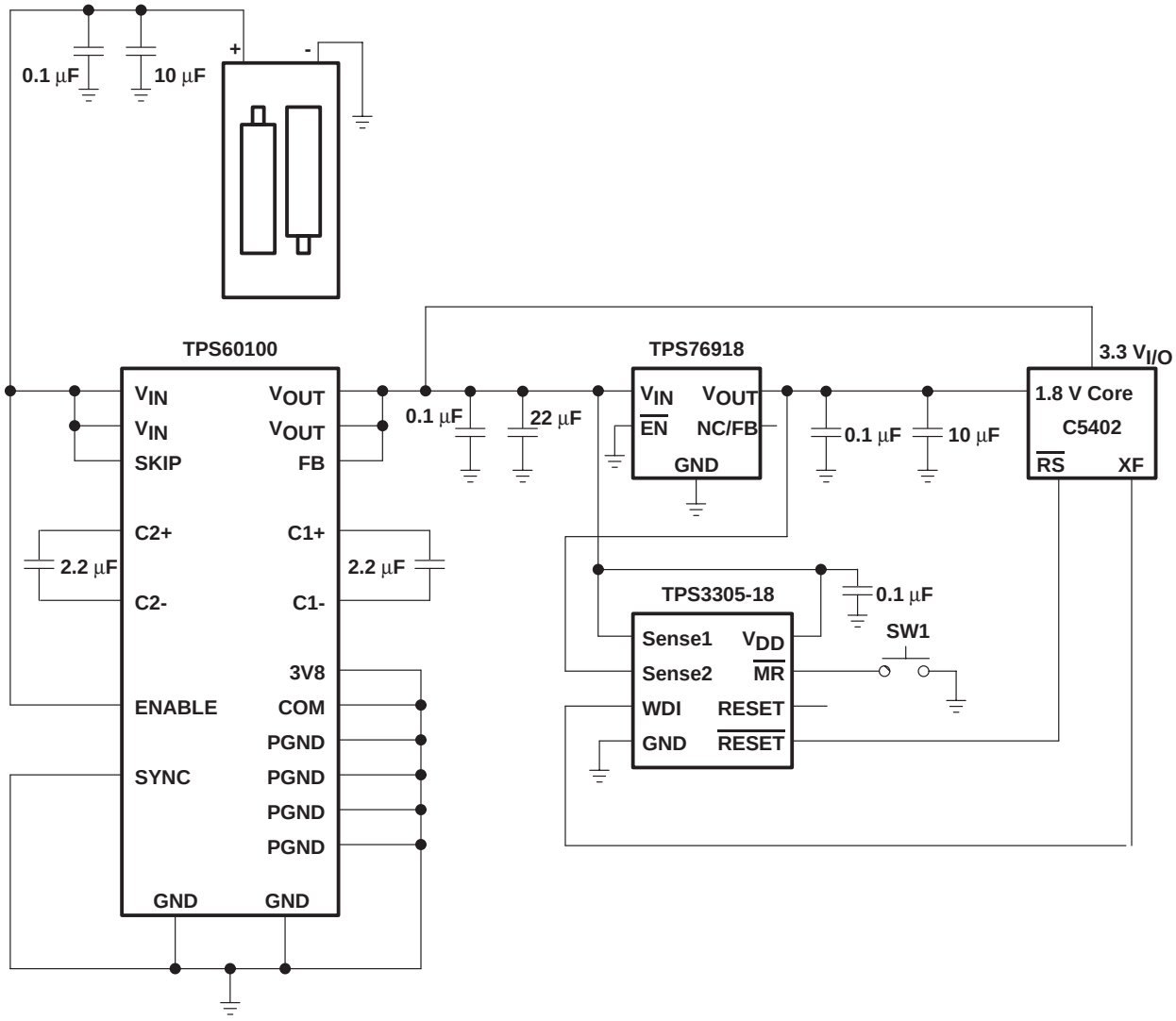
Design Problem

The TMS430VC5402 is ideally suited for today's portable applications powered by two alkaline or NiMH batteries. What high efficient, low-cost, compact power management solution produces a 1.8 V DSP core supply and a 3.3 V I/O supply, and provides power-system monitoring for proper DSP operation?

Solution

Start with the TPS60100 inductorless dc-to-dc converter to boost the battery voltage to 3.3 V. The TPS60100 generates up to 200 mA to directly power the I/O and peripheral circuits, and can supply power to the TPS76918 low-dropout series regulator which produces 1.8 V at up to 100 mA for the DSP core voltage. Both the 3.3-V and 1.8-V supplies are monitored by a TPS3305-18 dual-supply voltage supervisor, which holds the TMS320VC5402 in reset mode when either supply is below its proper operating range. The 'VC5402 XF signal can also be used to control the TPS3305-18 watchdog-timer function. A user-selectable jumper is included to disable the watchdog if desired.

Design Schematic



TPS60100 Charge Pump

The TPS60100 step-up, regulated charge pump generates a 3.3-V ±4% output voltage from the 1.8-V to 3.6-V input voltage (unregulated voltage from the pair of AA alkaline dry cells). Output current is 200 mA. Only four external capacitors are needed to build a complete low-noise dc/dc converter. The push-pull operating mode of two single-ended charge pumps assures the low output voltage ripple as current is continuously transferred to the output. This design requires no inductors and has low EMI.

Capacitor Selection

The TPS60100 requires only four external capacitors. Their values are closely linked to the output current capacity, output noise requirements, and mode of operation. Generally, the transfer capacitors will be the smallest. The input capacitor improves system efficiency by reducing the input impedance and stabilizes the input current. It is recommended that the input capacitor be about two to four times larger that the transfer capacitors. The output capacitor can be selected to be 5 to 50 times larger than the transfer capacitors, depending on the mode of operation and ripple tolerance. Tables 1 and 2 show capacitor values recommended for low quiescent-current operation (pulse-skip mode) and for low output-voltage ripple operation (constant-frequency mode). The smallest-size capacitors are recommended.

Table 1. Recommended Capacitor Values for Low Quiescent-Current Operation† (Pulse-Skip Mode)

V_{IN} [V]	I_O [mA]	C_{IN} [µF]		C_{xF} [µF]	C_O [µF]		OUTPUT VOLTAGE RIPPLE Vpp [mV]
		TANTALUM	CERAMIC		TANTALUM	CERAMIC	
2.4	150	10		2.2	22		90
2.4	150		10 (X5R)	2.2		22 (X5R)	45
2.4	200	10		2.2	22		55
2.4	200		10 (X5R)	2.2		22 (X5R)	30

† All measurements are done with additional 1-µF X7R ceramic capacitors at input and output.

Table 2. Recommended Capacitor Values for Low Output-Voltage Ripple Operation† (Constant-Frequency Mode)

V_{IN} [V]	I_O [mA]	C_{IN} [µF]		C_{xF} [µF]	C_O [µF]		OUTPUT VOLTAGE RIPPLE Vpp [mV]
		TANTALUM	CERAMIC		TANTALUM	CERAMIC	
2.4	150	10		2.2	22		13
2.4	150		10 (X5R)	2.2		22 (X5R)	4
2.4	200	10		2.2	22		15
2.4	200		10 (X5R)	2.2		22 (X5R)	5

† All measurements are done with additional 1-µF X7R ceramic capacitors at input and output.

For the TPS60100, the optimum utilization of board space can be achieved using Sprague's 595D-series capacitors for input and output (see Table 3).

Table 3. Recommended Output and Input Capacitors

MANUFACTURER	PART NUMBER	CAPACITANCE	TYPE
Taiyo Yuden	EMK316BJ105KF-T	1 µF	Ceramic
	EMK316BJ225KL-T	2.2 µF	Ceramic
	LMK325BJ106MN-T	10 µF	Ceramic
	LMK432BJ226MM-T	22 µF	Ceramic
AVX		1 µF	Ceramic
		2.2 µF	Ceramic
	TPSC106025R0500	10 µF	Tantalum
	TPSC226016R0375	22 µF	Tantalum
Sprague	595D106X0016B2T	10 µF	Tantalum
	595D226X0025D2T	22 µF	Tantalum
Kemet	T494C106M010AS	10 µF	Tantalum
	T494C226M010AS	22 µF	Tantalum

Table 4 lists the manufacturers of recommended capacitors. In most applications, surface-mount tantalum capacitors will be the right choice. However, ceramic capacitors will provide the lowest output-voltage ripple due to their typically-lower ESR.

Table 4. Recommended Capacitor Manufacturers

MANUFACTURER	CAPACITOR TYPE	INTERNET
Taiyo Yuden	X7R/X5R ceramic	www.t–yuden.com
AVX	X7R/X5R ceramic TPS-series tantalum	www.avxcorp.com
Sprague	595D-series tantalum	www.vishay.com
Kemet		www.kemet.com

Power Dissipation

The power dissipated in the TPS60100 depends on output current and its approximate value is calculated by: $P_{DISS} = I_O \times (2\ VIN - V_O)$, for $I_Q << I_O$. P_{DISS} must be lower than that allowed by the package rating.

TPS76918 LDO Voltage Regulator

The TPS76918 low-dropout (LDO) regulator has been optimized for use in battery-operated equipment. It features extremely-low dropout voltage, low quiescent current (17-μA nominal, 25-μA maximum), miniaturized packaging, and an enable input to reduce supply current to less than 1 μA when the regulator is turned off. This regulator features low dropout voltages and ultra-low quiescent current in comparison to conventional LDO regulators. Offered in 5-terminal small-outline integrated-circuit SOT-23 package, the TPS76918 is ideal for micropower operations and in applications where board space is at a premium. Since the PMOS pass element is a voltage-driven device, the quiescent current is ultra low and stable over the entire range of output-load current (0 mA to 100 mA).

External Capacitor Requirements

Although not required, a 0.047-μF or larger ceramic bypass input capacitor, connected between IN and GND and located close to the TPS76918, is recommended to improve transient response and noise rejection. A higher-value electrolytic input capacitor may be necessary if large, fast rise-time load transients are anticipated and the device is located several inches away from the power source. Like all low-dropout regulators, the TPS76918 requires an output capacitor connected between OUT and GND to stabilize the internal-control loop. The minimum recommended capacitance is 4.7 μF. The equivalent series resistance (ESR) of the capacitor should be between 0.2 Ω and 10 Ω. to ensure stability. Capacitor values larger than 4.7 μF are acceptable and allow the use of smaller ESR values. Capacitances less than 4.7 μF are not recommended because they require careful selection of the ESR to ensure stability. Solid tantalum-electrolytic, aluminum-electrolytic, and multilayer-ceramic capacitors are all suitable, provided they meet the requirements described above. Most of the commercially-available 4.7-μF surface-mount solid-tantalum capacitors, including devices from Sprague, Kemet, and Nichico, meet the ESR requirements stated above. Multilayer-ceramic capacitors may have very small equivalent series resistances and may thus require the addition of a low-value series resistor to ensure stability.

Table 5. External Capacitor Selection

PART NUMBER	MANUFACTURER	VALUE	MAX ESR†	SIZE (H×L×W)†
T494B475K016AS	KEMET	4.7 μF	1.5 Ω	1.9 × 3.5 × 2.8
195D106x0016x2T	SPRAGUE	10 μF	1.5 Ω	1.3 × 7.0 × 2.7
695D106x003562T	SPRAGUE	10 μF	1.3 Ω	2.5 × 7.6 × 2.5
TPSC475K035R0600	AVX	4.7 μF	0.6 Ω	2.6 × 6.0 × 3.2

† Size is in mm. ESR is maximum resistance in ohms at 100 kHz and T_A = 25°C. Listings are sorted by height. Contact manufacturer for minimum ESR values.

Power Dissipation and Junction Temperature

Regulator operation is specified to a junction temperature of 125°C; the maximum junction temperature should be restricted to 125°C under normal operating conditions. This restriction limits the power dissipation the regulator can handle in any given application. To ensure that the junction temperature is within acceptable limits, calculate the maximum allowable dissipation $P_{D(max)}$, and the actual dissipation P_D, which must be less than or equal to $P_{D(max)}$. The maximum-power-dissipation limit is determined using the following equation:

$$P_{D(MAX)} = \frac{T_{J(MAX)} - T_A}{R_{\theta JA}}$$

Where:

$T_{J(max)}$ is the maximum-allowable junction temperature

R_{qJA} is the thermal resistance junction-to-ambient for the package, namely, 285°C/W for the 5-terminal SOT23.

T_A is the ambient temperature.

The regulator dissipation is calculated as:

$$P_D = \left(V_I - V_O\right) \times I_O$$

Power dissipation resulting from quiescent current is negligible. Excessive power dissipation triggers the thermal protection circuit.

Regulator Protection

The TPS76918 PMOS-pass transistor has a built-in back diode that safely conducts reverse current when the input voltage drops below the output voltage (for example, during power down). Current is conducted from the output to the input and is not internally limited. If extended reverse-voltage operation is anticipated, external limiting might be appropriate. The TPS76918 features internal current limiting and thermal protection. During normal operation, the TPS76918 limits output current to approximately 300 mA. When current limiting engages, the output voltage scales back linearly until the overcurrent condition ends. While current limiting is designed to prevent gross device failure, care should be taken not to exceed the power dissipation ratings of the package. If the temperature of the device exceeds approximately 165°C, the thermal-protection circuitry shuts it down. Regulator operation resumes once the device has cooled down below approximately 140°C.

TPS3305-18 Supply Voltage Supervisor

The TPS3305 is a micropower-supply voltage supervisor designed for circuit initialization, primarily in DSP and processor-based systems which require two supply voltages. The product spectrum of the TPS3305 is designed to monitor two independent-supply voltages of 3.3 V and 1.8 V.

During power-on, $\overline{\text{RESET}}$ is asserted when the supply voltage becomes higher than 1.1 V. Thereafter, the supply-voltage supervisor monitors the SENSE inputs and keeps $\overline{\text{RESET}}$ active as long as SENSE remains below the threshold voltage V_{IT+}. An internal timer delays the return of the $\overline{\text{RESET}}$ output to the inactive state (high) to ensure proper system reset. The delay time, $t_{d\ typ}$ = 200 ms, starts after the SENSE1 and SENSE2 inputs have risen above the threshold voltage V_{IT+}. When the voltage at the input of SENSE1 or SENSE2 drops below the threshold voltage V_{IT-}, the $\overline{\text{RESET}}$ output becomes active (low) again. The TPS3305-18 integrates a watchdog timer that is periodically triggered by a positive or negative transition of WDI. When the supervising system fails to retrigger the watchdog circuit within the time-out interval, $t_{t(out)}$ = 1.6 seconds, $\overline{\text{RESET}}$ becomes active for the time period t_d. This event also reinitializes the watchdog timer. Leaving WDI unconnected disables the watchdog. The TPS3305-18 incorporates a manual reset input $\overline{\text{MR}}$. A low level at $\overline{\text{MR}}$ causes $\overline{\text{RESET}}$ to become active. In addition to the active-low RESET output, the TPS3305-18 includes an active-high RESET output.

Table 6. Function/Truth Table

$\overline{\text{MR}}$	SENSE1>V_{IT1}	SENSE2>V_{IT2}	$\overline{\text{RESET}}$	RESET
L	X†	X†	L	H
H	0	0	L	H
H	0	0	L	H
H	0	1	L	H
H	0	1	L	H
H	1	0	L	H
H	1	0	L	H
H	1	1	L	H
H	1	1	L	L

References

1. *TPS60100 Regulated 3.3-V High-Power Low-Noise Charge Pump DC/DC Converter* data sheet, literature number SLVS213A
2. *TPS60100 EVM: TPS60100EVM-131*, literature number SLVP131
3. Application report: *TPS6010X/TPS6011X Charge Pump,* literature number SLVA070
4. *TPS3305 Dual Processor Supervisors* data sheet, literature number SLVS198
5. *TPS76918 Ultra Low-Power 100-mA Low-Dropout Linear Regulator* data sheet, literature number SVLS203C
6. *TMS320VC5402 Low-Power DSP Demo Board*

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