

TPS5120 DUAL OUTPUT, TWO-PHASE SYNCHRONOUS BUCK DC/DC CONTROLLER

SLVS278E – AUGUST 2000 – REVISED MARCH 2003

typical design

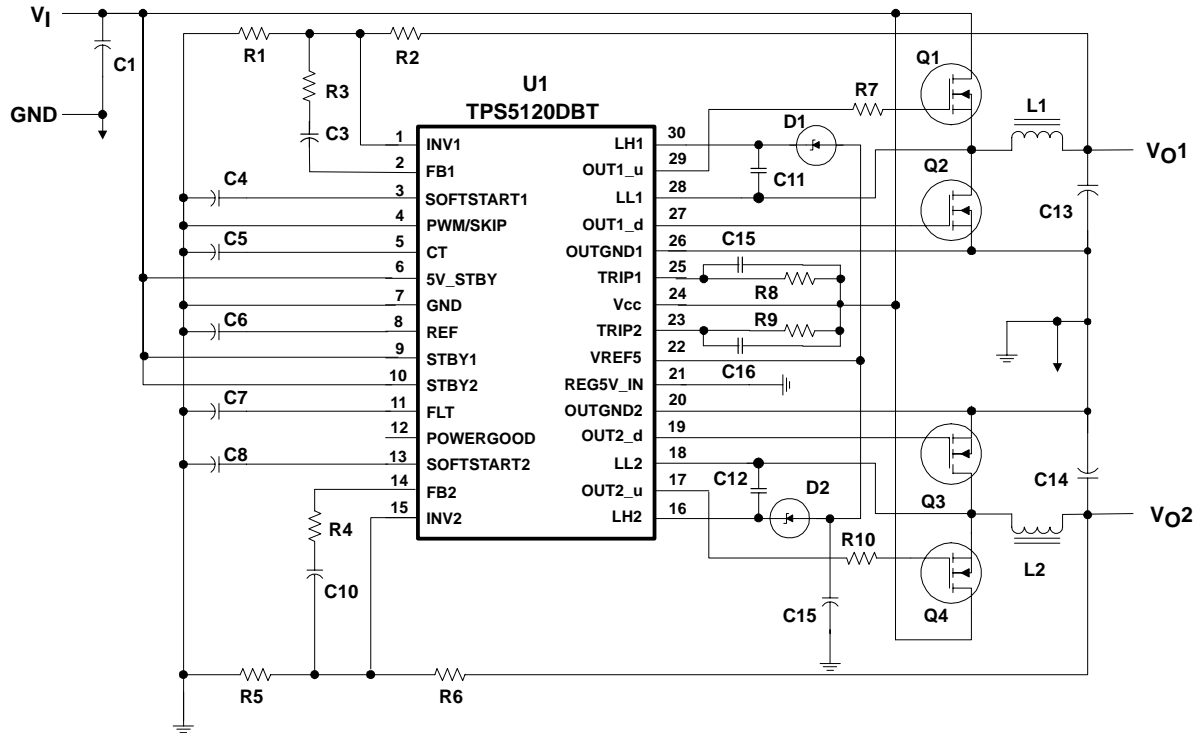


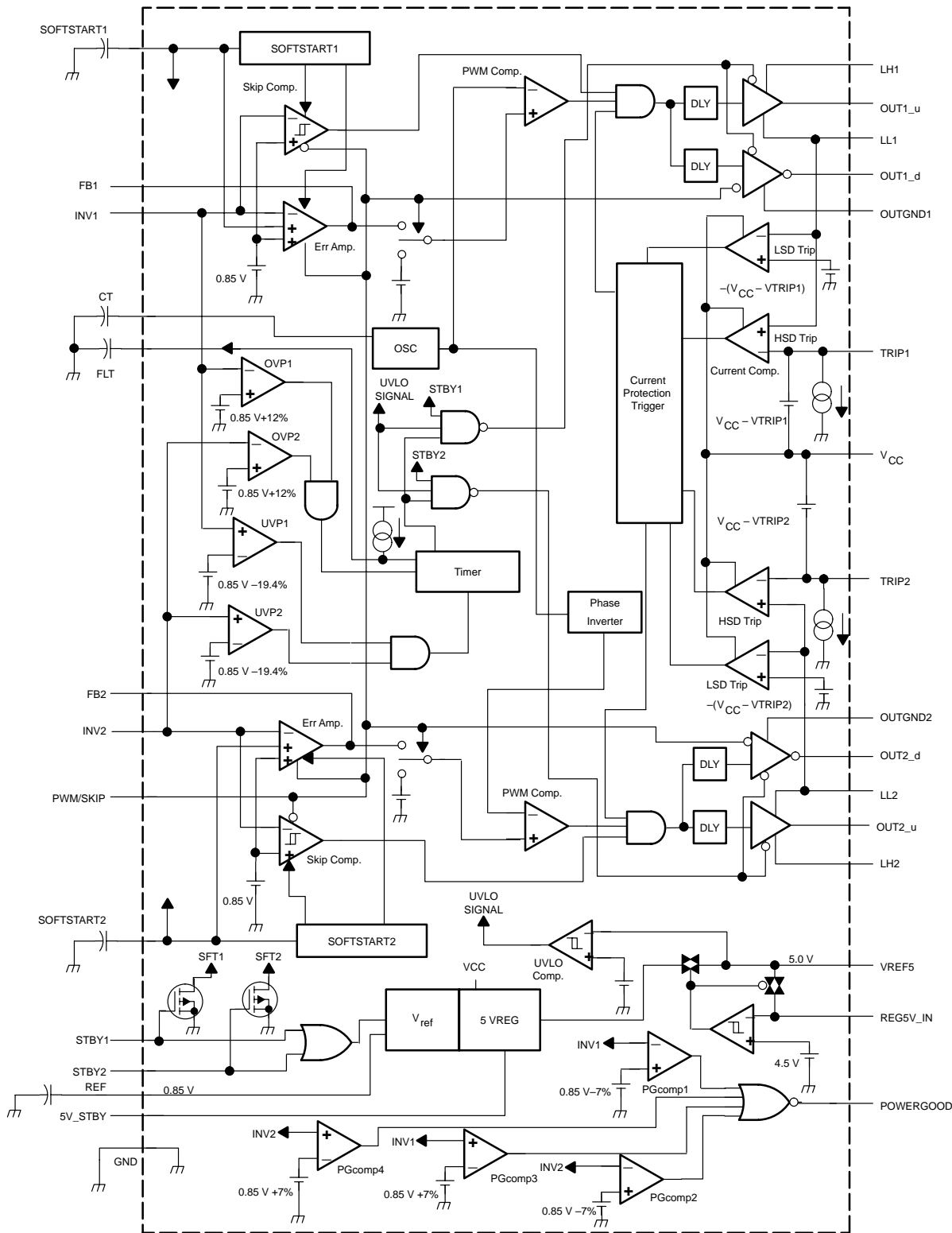
Figure 1. EVM Typical Design

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functional block diagram



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AVAILABLE OPTIONS

T _A	PACKAGE	EVM
	TSSOP (DBT)	
-40°C to 85°C	TPS5120DBT	TPS5120EVM-151
	TPS5120DBTR	

Terminal Functions

TERMINAL NAME	NO.	I/O	DESCRIPTION
CT	5	I/O	External capacitor from CT to GND for adjusting the triangle oscillator
FB1	2	O	Feedback output of CH1 error amplifier
FB2	14	O	Feedback output of CH2 error amplifier
GND	7		Control GND
INV1	1	I	Inverting input of the CH1 error amplifier, skip comparator, and OVP1/UVP1 comparator
INV2	15	I	Inverting input of the CH2 error amplifier, skip comparator, and OVP2/UVP2 comparator
LH1	30	I/O	Bootstrap capacitor connection for CH1 high-side gate drive
LH2	16	I/O	Bootstrap capacitor connection for CH2 high-side gate drive
LL1	28	I/O	Bootstrap this pin low for CH1 high-side gate driving return and output current protection. Connect this pin to the junction of the high-side and low-side FETs for a floating drive configuration.
LL2	18	I/O	Bootstrap this pin low for CH2 high-side gate driving return and output current protection. Connect this pin to the junction of the high-side and low-side FETs for a floating drive configuration.
OUT1_d	27	O	Gate drive output for CH1 low-side gate drive
OUT2_d	19	O	Gate drive output for CH2 low-side gate drive
OUT1_u	29	O	Gate drive output for CH1 high-side switching FETs
OUT2_u	17	O	Gate drive output for CH2 high-side switching FETs
OUTGND1	26		Ground for CH1 FET drivers
OUTGND2	20		Ground for CH2 FET drivers
POWERGOOD	12	O	Power good open-drain output. When low, POWERGOOD reports an output fail condition. PG comparators monitor both SMPS's over voltage and UVLO of VREF5. The threshold is ±7%. When the SMPS starts up, the POWERGOOD pin's output goes high. POWERGOOD also monitors VREF5's UVLO output.
PWM/SKIP	4	I	PWM/SKIP mode select pin. The PWM/SKIP pin is used to change the output's operating mode. If this terminal is lower than 0.5 V, it works in PWM mode. When a minimum voltage of 2 V is applied, the device operates in skip mode. In light load condition (< 0.2 A), the skip mode gives a short pulse to the low-side FETs instead of a full pulse. With this control, switching frequency is lowered and switching loss is reduced. Also, the output capacitor energy discharging through the output inductor and low-side FETs is stopped. Therefore, TPS5120 achieves a higher efficiency in light load conditions.
REF	8	O	0.85-V reference voltage output. The 0.85-V reference voltage is used for setting the output voltage and the voltage protection. This reference voltage is dropped down from a 5-V regulator.
REG5V_IN	21	I	External 5-V input
FLT	11	I/O	Fault latch timer pin. An external capacitor is connected between FLT and GND to set the FLT enable time up.
SOFTSTART1	3	I/O	External capacitor from SOFTSTART1 to GND for CH1 softstart control. Separate soft-start terminals make it possible to set the start-up time of each output independently.
SOFTSTART2	13	I/O	External capacitor from SOFTSTART2 to GND for CH2 softstart control. Separate soft-start terminals make it possible to set the start-up time of each output independently.
STBY1	9	I	Standby control for CH1. SMPS1 can be switched into standby mode separately by grounding the STBY1 pin.
STBY2	10	I	Standby control for CH2. SMPS2 can be switched into standby mode separately by grounding the STBY2 pin.
TRIP1	25	I	External resistor connection for CH1 output current control



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Terminal Functions (Continued)

TERMINAL NAME	NO.	I/O	DESCRIPTION
TRIP2	23	I	External resistor connection for CH2 output current control
VCC	24		Supply voltage input
VREF5	22	O	5-V internal regulator output
5V_STBY	6	I	5-V linear regulator control

detailed description

switching-mode power supply (SMPS) 1, 2

TPS5120 includes dual SMPS controllers that operate 180° out of phase and at the same frequency. Both channels have standby and softstart.

5-V regulator

An internal linear voltage regulator is used for the high-side driver bootstrap voltage and source of VREF (0.85 V). When the 5-V regulator is disconnected from the MOSFET drivers, it is only used for the source of VREF. Since the input voltage range is from 4.5 V to 28 V, this feature offers a fixed voltage for the bootstrap voltage so that the drive design is much easier. It is also used for powering the low-side driver. The tolerance is 4%. The 5-V regulator is disabled when STBY1, STBY2, and 5V_STBY are all set low.

5-V switch

If the internal 5-V switch senses the 5-V input from the REG5V_IN pin, the internal 5-V linear regulator is disconnected from the MOSFET drivers. The external 5 V is then used for both the low-side driver and the high-side bootstrap, thus, increasing the efficiency.

error amplifier

Each channel has its own error amplifier to regulate the output voltage of the synchronous buck converter. It is used in the PWM mode for the high output current condition (> 0.2 A). The unity gain bandwidth is 2.5 MHz. This decreases the amplifier delay during fast load transients and contributes to a fast transient response.

skip comparator

In skip mode, each channel has its own hysteretic comparator to regulate the output voltage of the synchronous buck converter. The hysteresis is set internally and is typically set at 9 mV. The delay from the comparator input to the driver output is typically 1.2 μs.

low-side driver

The low-side driver is designed to drive low $r_{ds(on)}$ N-channel MOSFETs. The maximum drive voltage is 5 V from VREF5. The current rating of the driver is typically 1.5 A at source and sink.

high-side driver

The high-side driver is designed to drive low $r_{ds(on)}$ N-channel MOSFETs. The current rating of the driver is 1.2 A at source and sink. When configured as a floating driver, the bias voltage to the driver is developed from VREF5, limiting the maximum drive voltage between OUTx_u and LLx to 5 V. The maximum voltage that can be applied between LHx and OUTGND is 33 V.

deadtime

Deadtime prevents shoot through current from flowing through the main power FETs during switching transitions by actively controlling the turnon time of the MOSFETs drivers.



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detailed description (continued)

current protection

Overcurrent protection is achieved by comparing the drain-to-source voltage of the high-side and low-side MOSFET devices to a set-point voltage. This voltage is set using an external resistor between V_{CC} and the TRIP1 or TRIP2 terminals. If the drain-to-source voltage up exceeds the set-point voltage during high-side conduction, the current limit circuit terminates the high-side driver pulse. If the set-point voltage is exceeded during low-side conduction, the low-side pulse is extended through the next cycle. Together this action has the effect of decreasing the output voltage until the undervoltage protection circuit is activated and the fault latch is set and both the high and low-side MOSFET drivers are shut off.

overvoltage protection

For overvoltage protection (OVP), the TPS5120 monitors INV pin voltage. When the INV voltage is higher than 0.95 V (+12%), the OVP comparator output goes high and the FLT timer starts to charge an external capacitor connected to FLT. After a set time, the FLT circuit latches the MOSFET drivers off.

undervoltage protection

For undervoltage protection (UVP), the TPS5120 monitors INV pin voltage. When the INV voltage is lower than 0.68 V (–19.4%), the OVP comparator output goes high, and the FLT timer starts to charge an external capacitor connected to FLT. Also, when the current comparator triggers the OCP, the UVP comparator detects the under voltage output and starts the FLT capacitor charge. After a set time, the FLT circuit latches off all of the MOSFET drivers.

FLT

When an OVP or UVP comparator output goes high, the FLT circuit starts to charge the FLT capacitor. If the FLT pin voltage goes beyond a constant level, the TPS5120 latches the MOSFET drivers. At this time, the state of MOSFET is different depending on the OVP alert and the UVP alert. Also, the enable time used to latch the MOSFET driver is decided by the capacity of the FLT capacitor. The charging constant current value is also different depending on whether it is an OVP alert or a UVP alert. The difference is shown in the following equation:

$$\text{FLT source current (OVP)} = \text{FLT source current (UVP)} \times 5$$

shutdown

The TPS5120 can be shut down by grounding STBY1, STBY2, and 5V_STBY. The shutdown current is as low as 1 μA .

UVLO

When the input voltage goes up to about 4 V, the TPS5120 is operational. When the input voltage is lower than the turnon value, the device is turned off. The typical hysteresis voltage is 40 mV.

phase inverter

Phase inverter controls the phase of SMPS1 and SMPS 2. SMPS1 operates in phase with the OSC. SMPS2 operates 180° out of phase from SMPS1. This allows smaller input capacitors to be used.

oscillator

TPS5120 has a triangle oscillator generator internal to the IC. The oscillation frequency is set by the size of the capacitor connected to the CT pin. The voltage amplitude is 0.43 V ~ 1.17 V.



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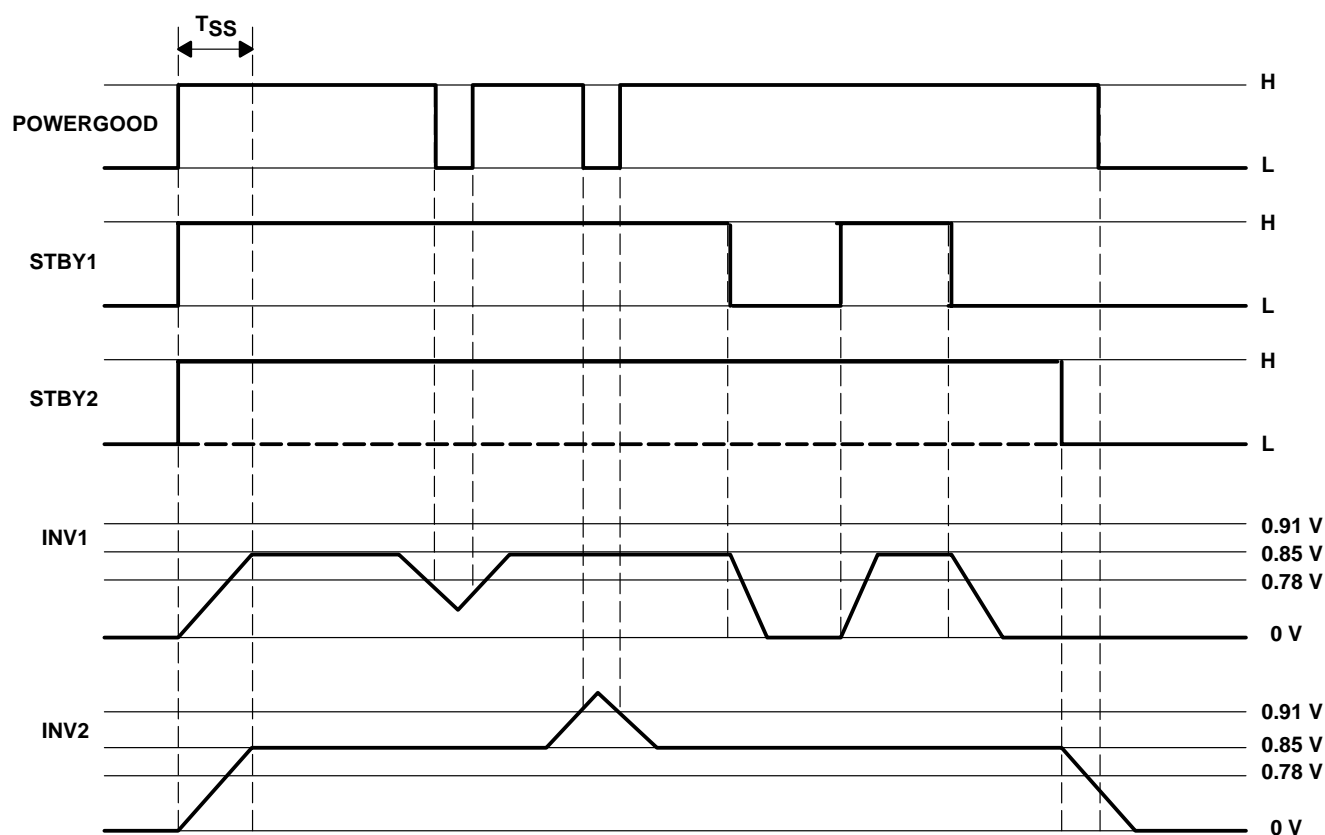
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Table 1. Logic Chart

5V_STBY	STBY1	STBY2	SMPS1	SMPS2	5 V REGULATOR	POWERGOOD
L	L	L	Disable	Disable	Disable	Disable
L	L	H	Disable	Enable	Enable	Active†
L	H	L	Enable	Disable	Enable	Active†
L	H	H	Enable	Enable	Enable	Active
H	L	L	Disable	Disable	Enable	L
H	L	H	Disable	Enable	Enable	Active†
H	H	L	Enable	Disable	Enable	Active†
H	H	H	Enable	Enable	Enable	Active

† PG is set high during a softstart.

POWERGOOD timing sequence



During a softstart, this channel's powergood comparator output is fixed low (POWERGOOD output is high).

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absolute maximum ratings over operating free-air temperature (unless otherwise noted)†

Supply voltage, V_{CC} (see Note 1)	–0.3 V to 30 V
Input voltage: INV1, INV2, CT, PWM/SKIP, REG5V_IN, SOFTSTART1, SOFTSTART2,	–0.3 V to 7 V
FLT, POWERGOOD	–0.3 V to 7 V
STBY1, STBY2, 5V_STBY, TRIP1, TRIP2	–0.3 V to 30 V
Output voltage: LL1, LL2	–1.0 V to 30 V
OUT1_u, OUT2_u	–1.0 V to 35 V
LH1, LH2	–0.3 V to 35 V
OUT1_d, OUT2_d, 5V_OUT, FB1, FB2	–0.3 V to 7 V
REF	–0.3 V to 3 V
OUT1_u, LH1 to LL1	–0.3 V to 7 V
OUT2_u, LH2 to LL2	–0.3 V to 7 V
Power dissipation ($T_A \leq 25^\circ\text{C}$), P_D	874 mW
Operating free-air temperature range, T_A	–40°C to 85°C
Storage temperature range, T_{stg}	–55°C to 150°C

† Stresses beyond those listed under “absolute maximum ratings” may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under “recommended operating conditions” is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

- NOTES: 1. All voltage values are with respect to the network ground terminal unless otherwise noted.
 2. This rating is specified at duty = 10% on output rise and fall each pulse. Each pulse width (rise and fall) for the peak current should not exceed 2 μs .
 3. See Dissipation Rating Table for free-air temperature range above 25°C.

DISSIPATION RATING TABLE

PACKAGE	$T_A \leq 25^\circ\text{C}$	DERATING FACTOR	POWER DISSIPATION
	POWER RATING	ABOVE $T_A = 25^\circ\text{C}$	$T_A = 85^\circ\text{C}$
DBT	874 mW	6.993 mW/°C	454 mW

recommended operating conditions

		MIN	NOM	MAX	UNIT
Supply voltage, V_{CC}		4.5		28	V
Input voltage, V_I	INV1, INV2, CT, PWM/SKIP, SOFTSTART1, SOFTSTART2, FLT			6	V
	REG5V_IN, POWERGOOD	–0.1		5.5	
	STBY1, STBY2, 5V_STBY			28	
	OUT1_u, OUT2_u, LH1, LH2			33	
	TRIP1, TRIP2	–0.1		28	
Oscillator frequency, f_{osc}			300	500	kHz
Operating free-air temperature range, T_A		–40		85	°C



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electrical characteristics over recommended free-air temperature range, $V_{CC} = 7\text{ V}$ (unless otherwise noted)

reference voltage

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{ref}	Reference voltage			0.85		V
$V_{ref(tol)}$	Reference voltage tolerance	$T_A = 25^\circ\text{C}$, $I = 50\ \mu\text{A}$	-1%		1%	
		$T_A = -20^\circ\text{C}$ to 85°C , $I = 50\ \mu\text{A}$	-1.5%		1.5%	
		$T_A = -40^\circ\text{C}$ to 85°C , $I = 50\ \mu\text{A}$	-2%		2%	
$R_{(egin)}$	Line regulation	$V_{CC} = 4.5\text{ V}$ to 28 V , $I = 50\ \mu\text{A}$		0.05	3	mV
$R_{(egl)}$	Load regulation	$I = 0.1\ \mu\text{A}$ to 1 mA		0.15	5	mV

oscillator

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
f_{osc}	Frequency	PWM mode, $C_T = 44\text{ pF}$, $T_A = 25^\circ\text{C}$		300		kHz
V_{OH}	High level output voltage	DC	1	1.1	1.2	V
		$f_{osc} = 300\text{ kHz}$		1.17		
V_{OL}	Low level output voltage	DC	0.4	0.5	0.6	V
		$f_{osc} = 300\text{ kHz}$		0.43		

error amplifier

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{IO}	Input offset voltage	$T_A = 25^\circ\text{C}$		2	10	mV
	Open-loop voltage gain		50			dB
	Unity-gain bandwidth			2.5		MHz
$I_{(snk)}$	Output sink current	$V_O = 1\text{ V}$	0.3	0.7		mA
$I_{(src)}$	Output source current	$V_O = 1\text{ V}$	0.2	0.9		mA

skip comparator

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{hys}	Hysteresis window	SKIP mode		9		mV

duty control

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
DUTY	Maximum duty cycle	300 kHz, $V_I = 0\text{ V}$		83%		

control

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{IH}	High-level input voltage	STBY1, STBY2	2.2			V
		PWM/SKIP, 5V_STBY	2.2			
V_{IL}	Low-level input voltage	STBY1, STBY2			0.3	V
		PWM/SKIP, 5V_STBY			0.3	

5-V internal switch

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_{(TO_H)}$	Threshold		4.2		4.8	V
$V_{(TO_L)}$			4.1		4.7	
V_{hys}	Hysteresis		30		200	mV



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electrical characteristics over recommended free-air temperature range, $V_{CC} = 7\text{ V}$ (unless otherwise noted) (continued)

5-V regulator

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_O	Output voltage	$I_O = 0\text{ mA to }50\text{ mA}$, $T_A = 25^\circ\text{C}$	4.8		5.2	V
$R_{(egin)}$	Line regulation	$V_{CC} = 5.5\text{ V to }28\text{ V}$, $I = 10\text{ mA}$			20	mV
$R_{(egl)}$	Load regulation	$I = 1\text{ mA to }10\text{ mA}$, $V_{CC} = 5.5\text{ V}$			40	mV
I_{OS}	Short circuit output current	$5V_{REG} = 0\text{ V}$, $T_A = 25^\circ\text{C}$	65			mA
$V_{(TO_H)}$	UVLO threshold voltage	5V_OUT voltage	3.6		4.2	V
$V_{(TO_L)}$			3.5		4.1	
V_{hys}	Hysteresis	5V_OUT voltage	30		150	mV

output drivers

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
	OUT_u sink current	$V_O = 3\text{ V}$		1.2		A
	OUT_u source current	$V_O = 2\text{ V}$		-1.5		A
	OUT_d sink current	$V_O = 3\text{ V}$		1.5		A
	OUT_d source current	$V_O = 2\text{ V}$		-1.5		A
$I_{(TRIP)}$	TRIP pin current	$T_A = 25^\circ\text{C}$	11.5	13	14.5	μA

soft start

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$I_{(SOFT)}$	Soft start current		1.6	2.3	2.9	μA
$V_{(TO_H)}$	Threshold voltage (SKIP mode)			3.7		V
$V_{(TO_L)}$				2.5		

output voltage monitor

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
	OVP comparator threshold		0.91	0.95	0.99	V
	UVP comparator threshold		0.64	0.68	0.72	V
	PG comparator 1, 2 threshold		0.75	0.78	0.81	V
	PG comparator 3, 4 threshold		0.88	0.91	0.94	V
	PG propagation delay from INV to POWERGOOD	Turnon		13		μs
		Turnoff		1.2		
	Timer latch current source	UVP protection	1.5	2.3	3.1	μA
		OVP protection	8	11.5	15	

supply current

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
I_{CC}	Supply current	$T_A = 25^\circ\text{C}$, $CT = 0\text{ V}$, $INV = 0\text{ V}$		1.1	1.5	mA
$I_{CC(S)}$	Shutdown current	STBY 1, STBY2, 5V_STBY = 0 V		0.001	10	μA



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TYPICAL CHARACTERISTICS

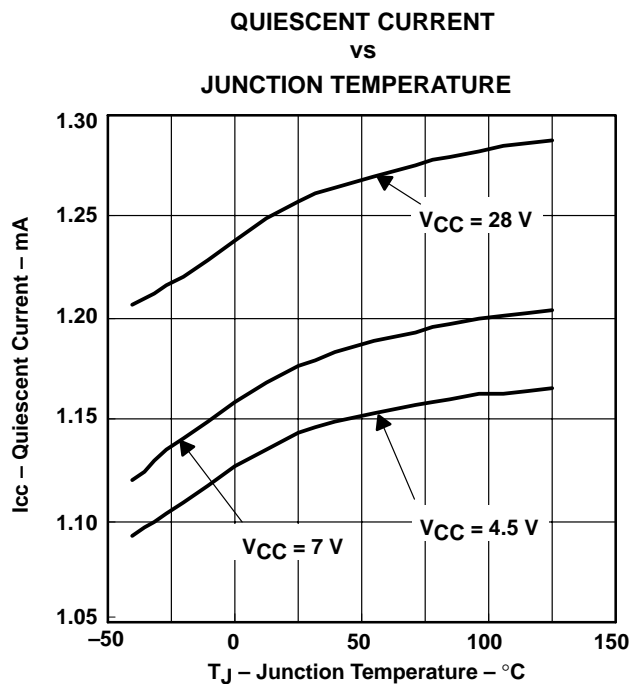


Figure 2

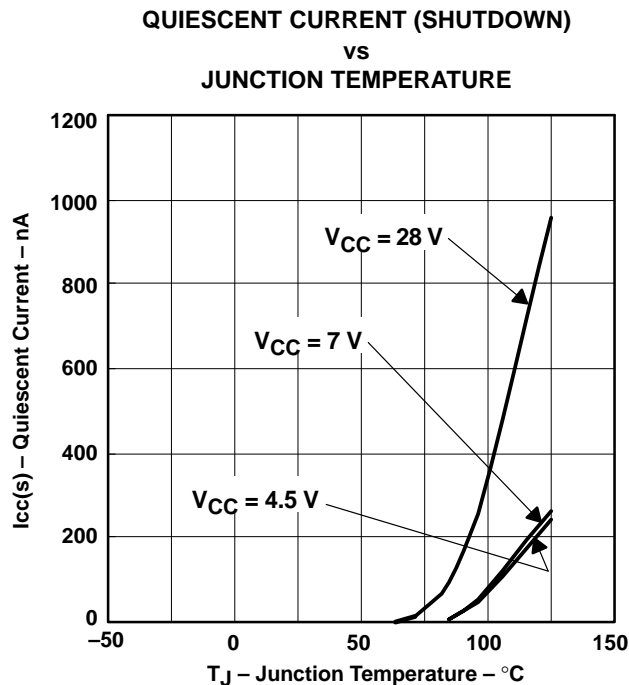


Figure 3

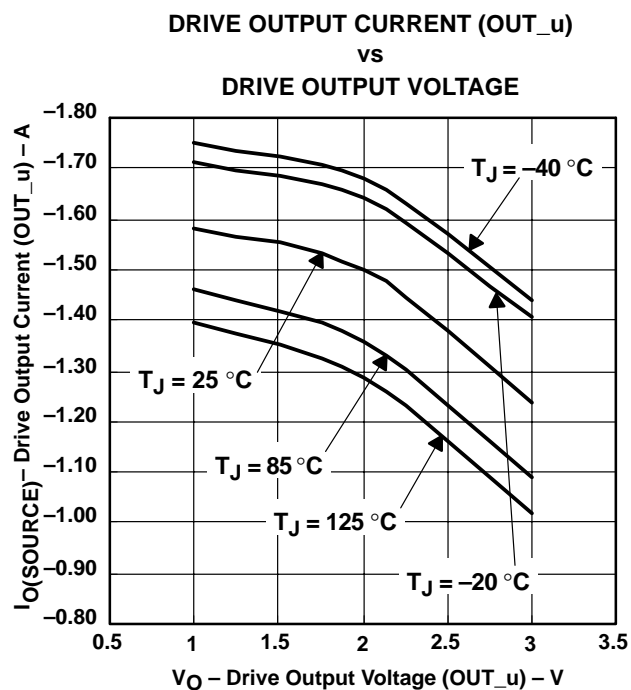


Figure 4

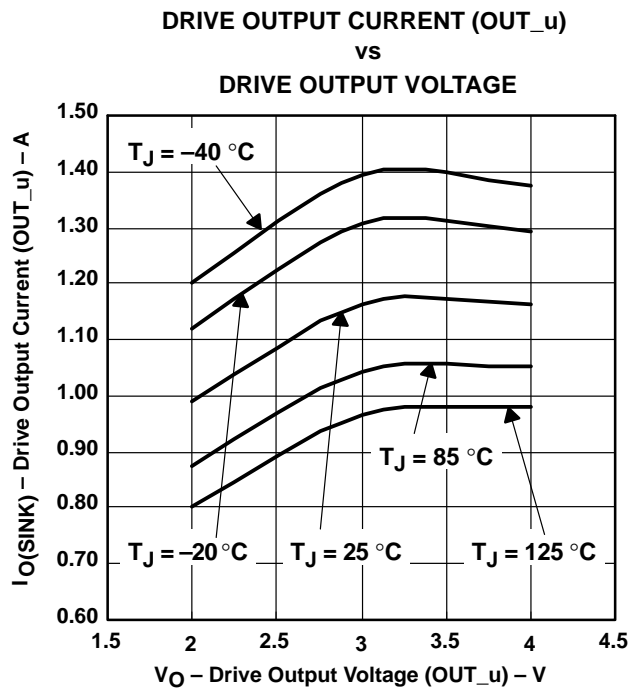


Figure 5



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TYPICAL CHARACTERISTICS

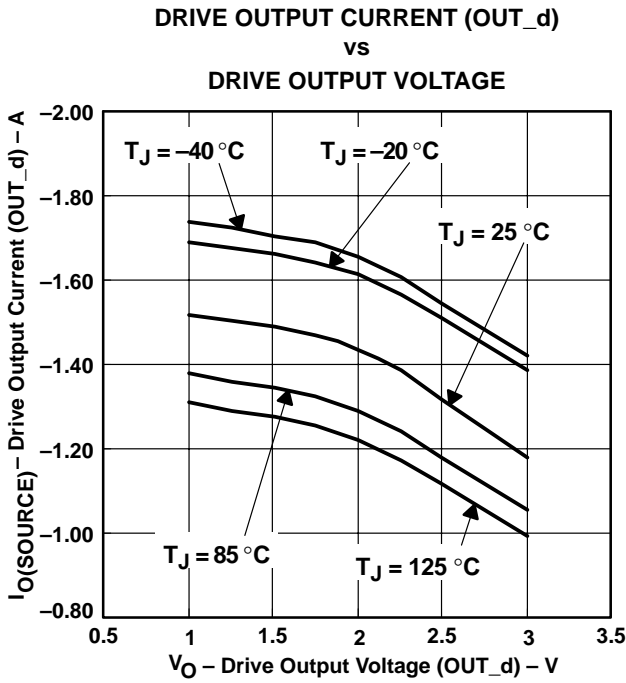


Figure 6

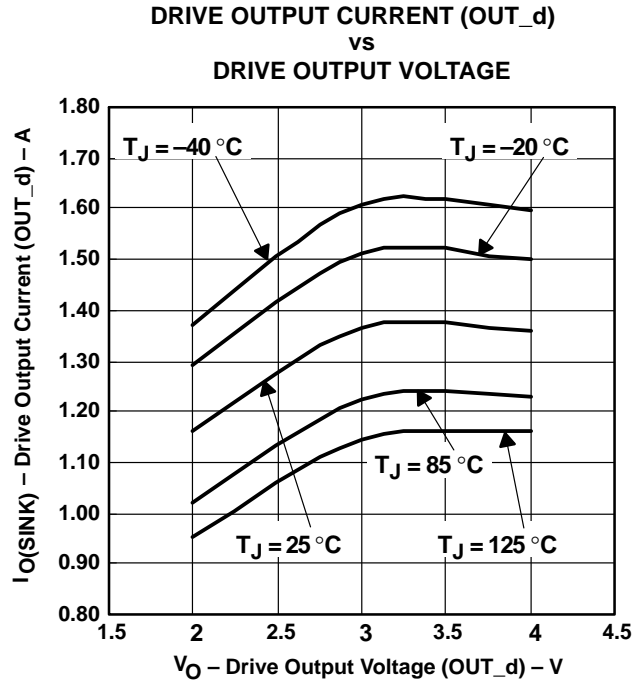


Figure 7

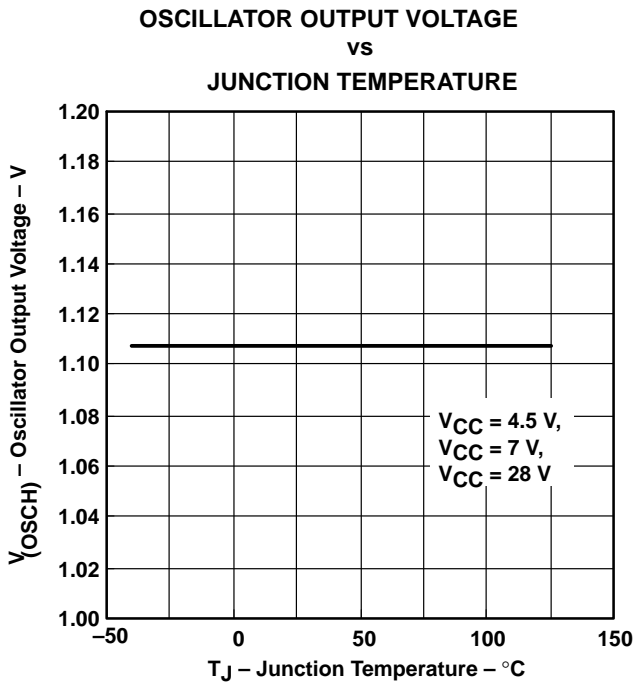


Figure 8

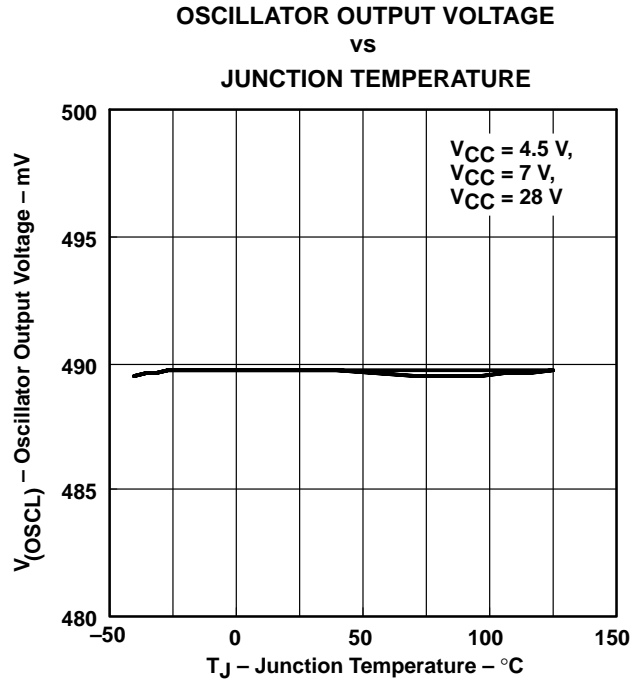


Figure 9

TYPICAL CHARACTERISTICS

**ERROR AMPLIFIER INPUT OFFSET VOLTAGE
vs
JUNCTION TEMPERATURE**

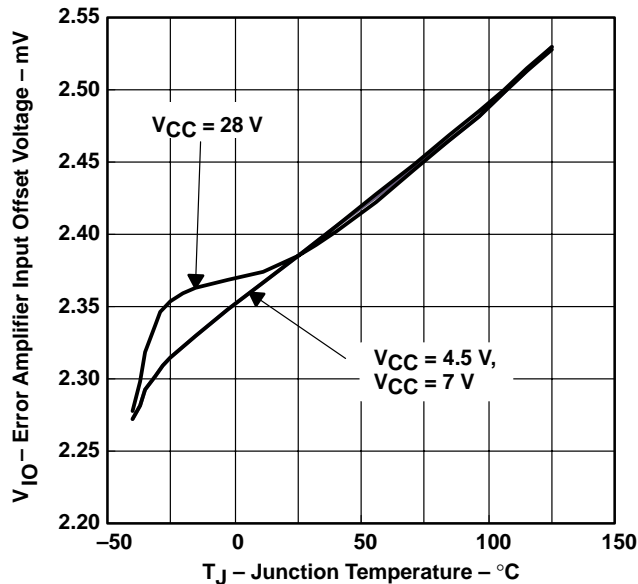


Figure 10

**ERROR AMPLIFIER OUTPUT VOLTAGE
vs
JUNCTION TEMPERATURE**

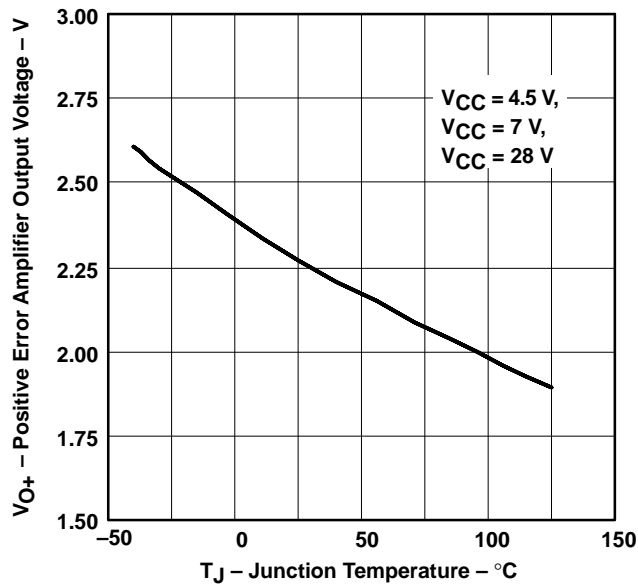


Figure 11

**ERROR AMPLIFIER OUTPUT VOLTAGE
vs
JUNCTION TEMPERATURE**

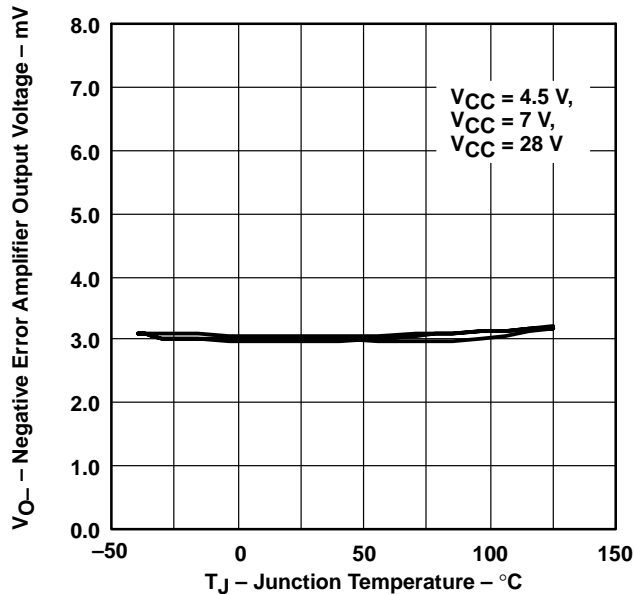


Figure 12

**SKIP COMPARATOR HYSTERESIS VOLTAGE
vs
JUNCTION TEMPERATURE**

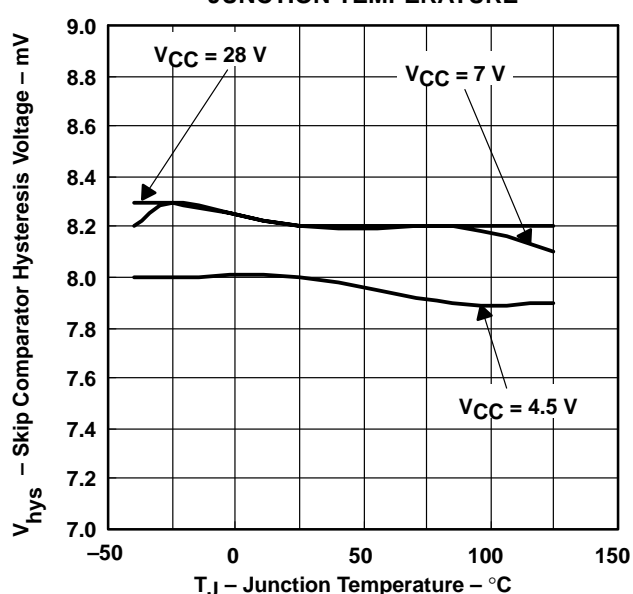


Figure 13

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TYPICAL CHARACTERISTICS

VREF5 OUTPUT VOLTAGE
vs
OUTPUT CURRENT

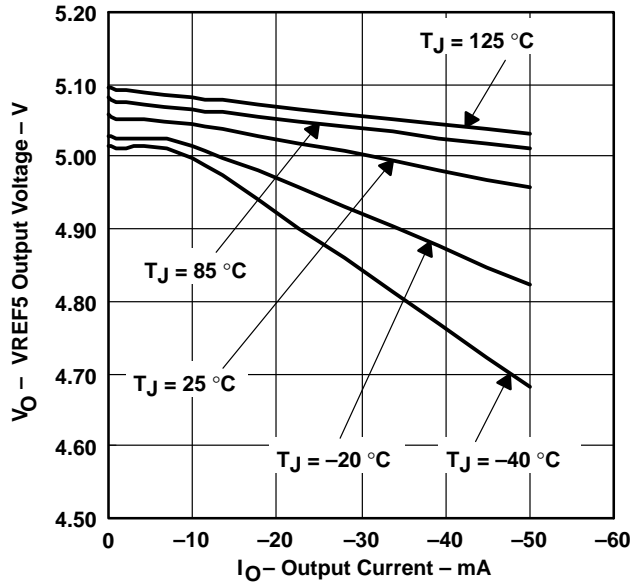


Figure 14

VREF5 SHORT-CIRCUIT OUTPUT CURRENT
vs
JUNCTION TEMPERATURE

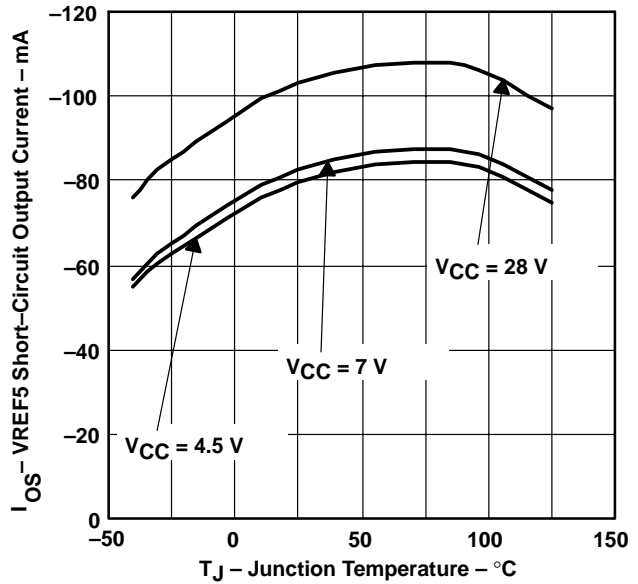


Figure 15

UVLO THRESHOLD VOLTAGE
vs
JUNCTION TEMPERATURE

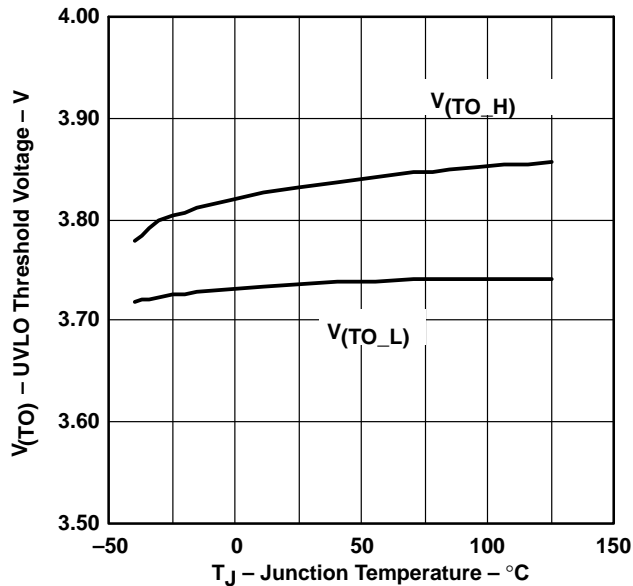


Figure 16

UVLO HYSTERESIS VOLTAGE
vs
JUNCTION TEMPERATURE

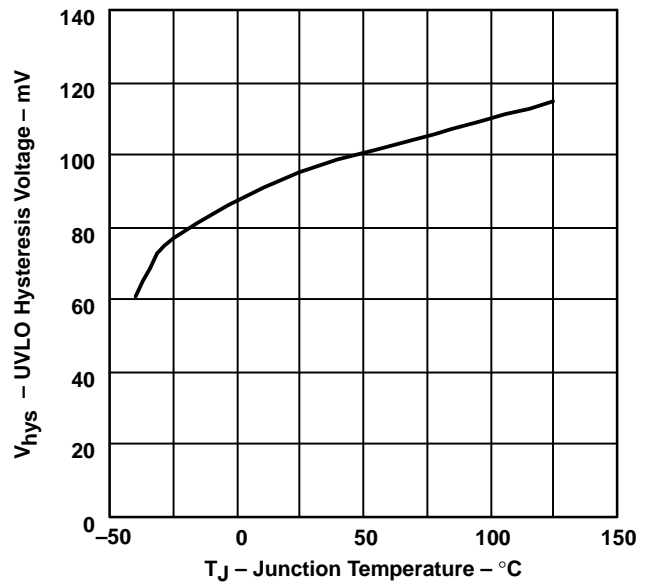


Figure 17

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TYPICAL CHARACTERISTICS

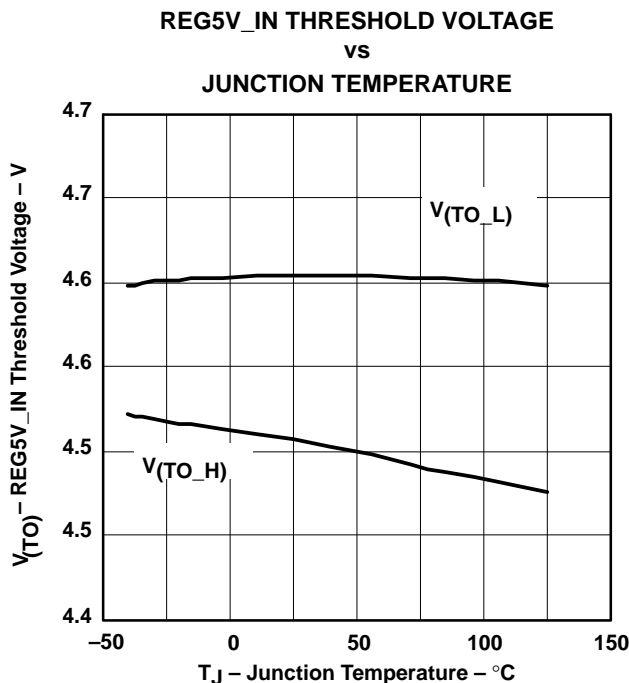


Figure 18

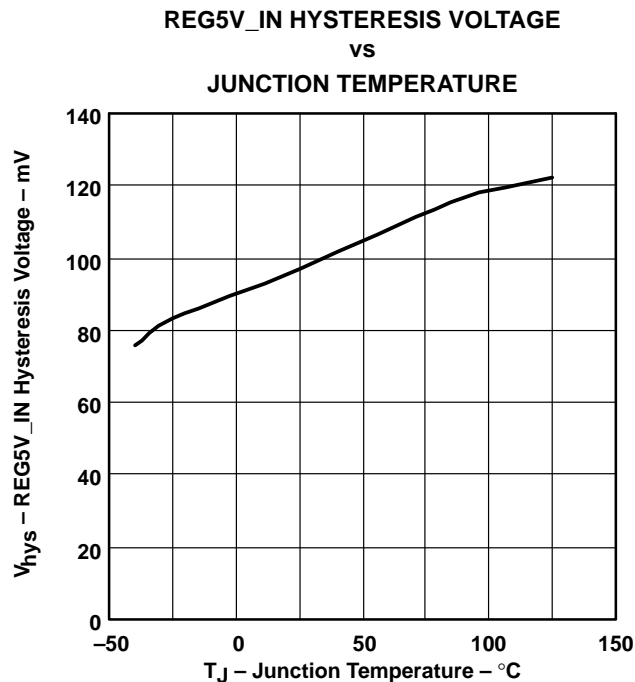


Figure 19

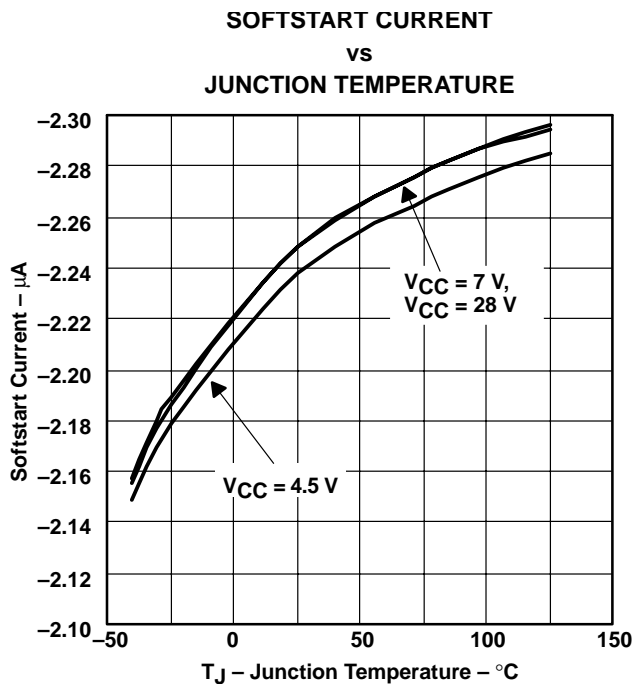


Figure 20

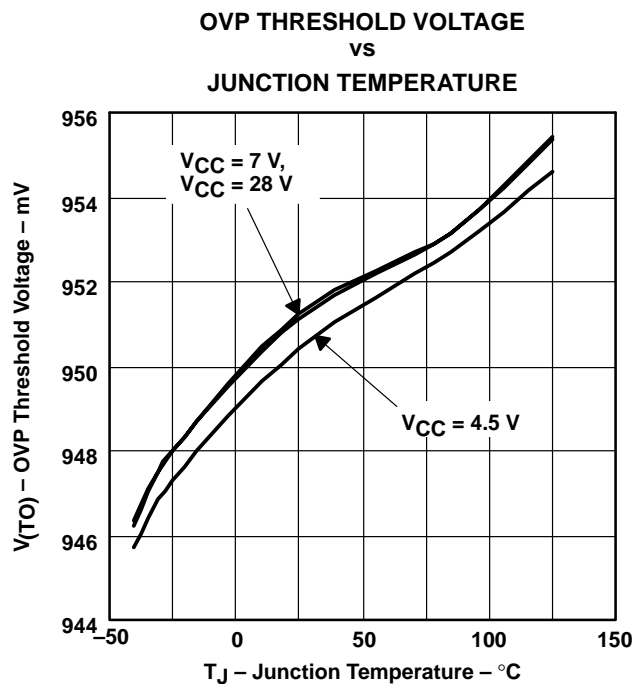


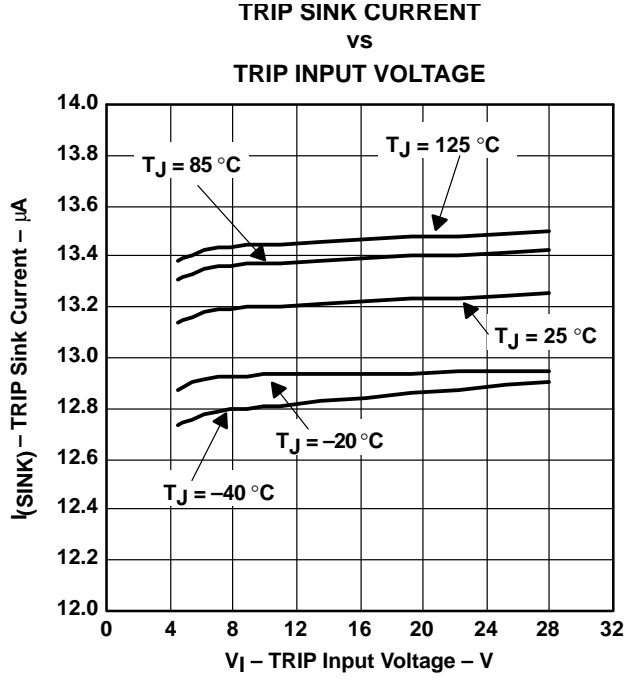
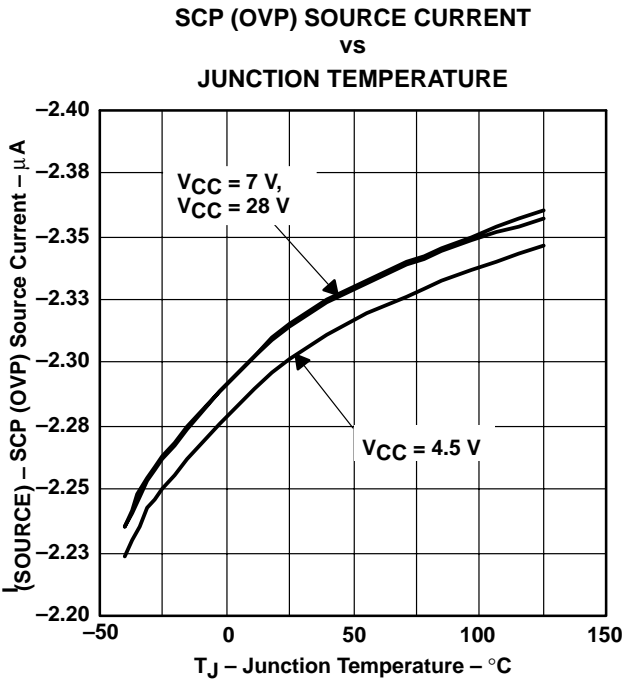
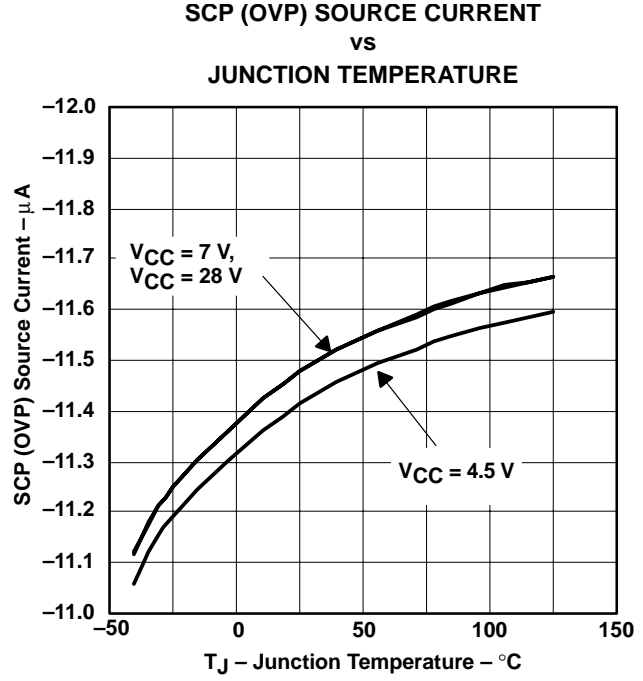
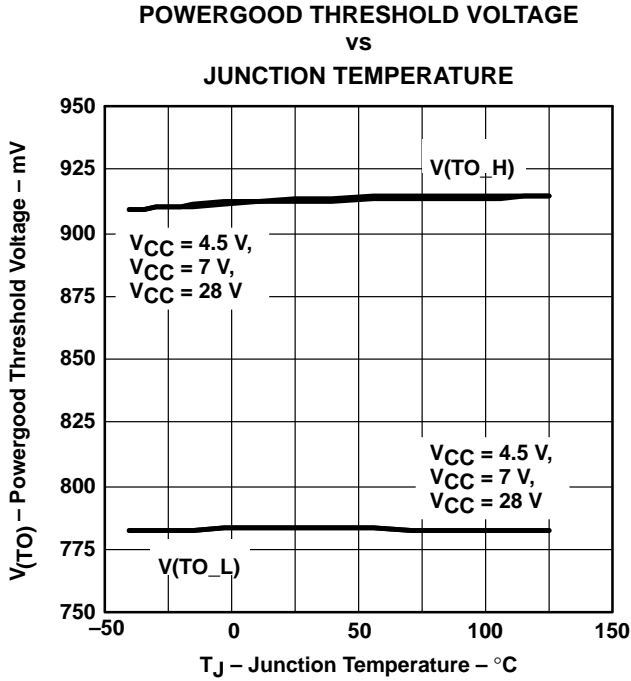
Figure 21



TPS5120 DUAL OUTPUT, TWO-PHASE SYNCHRONOUS BUCK DC/DC CONTROLLER

SLVS278E – AUGUST 2000 – REVISED MARCH 2003

TYPICAL CHARACTERISTICS

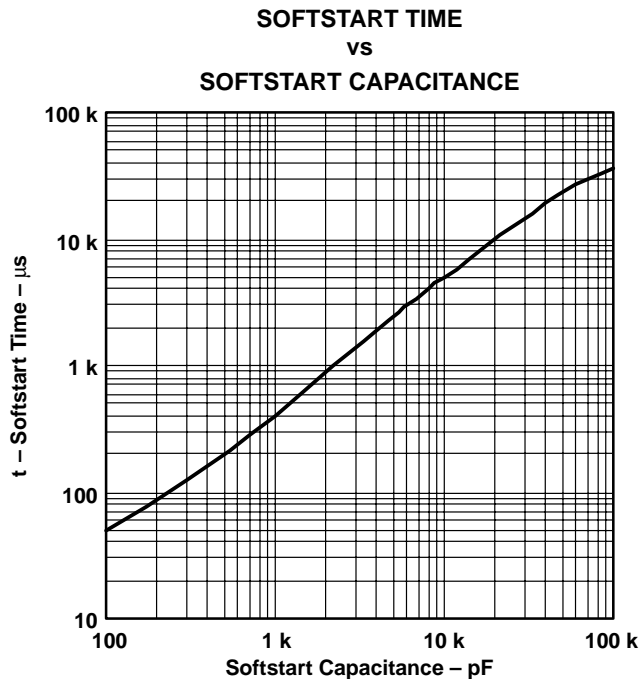
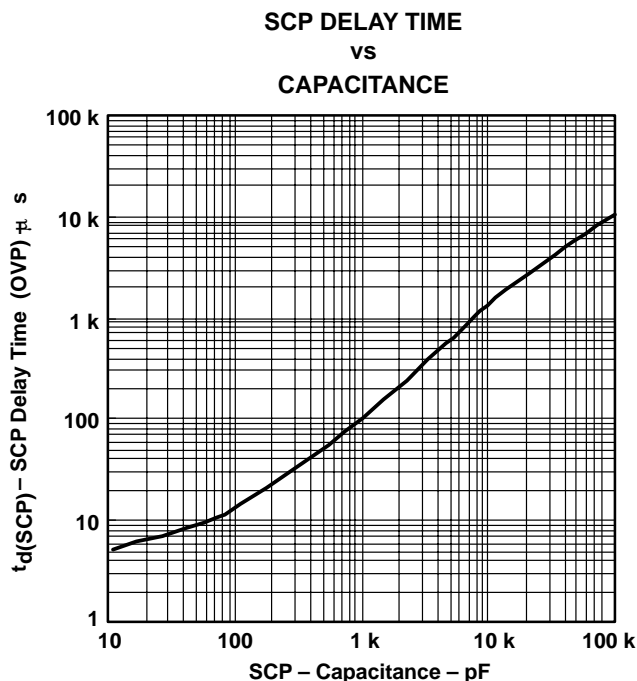
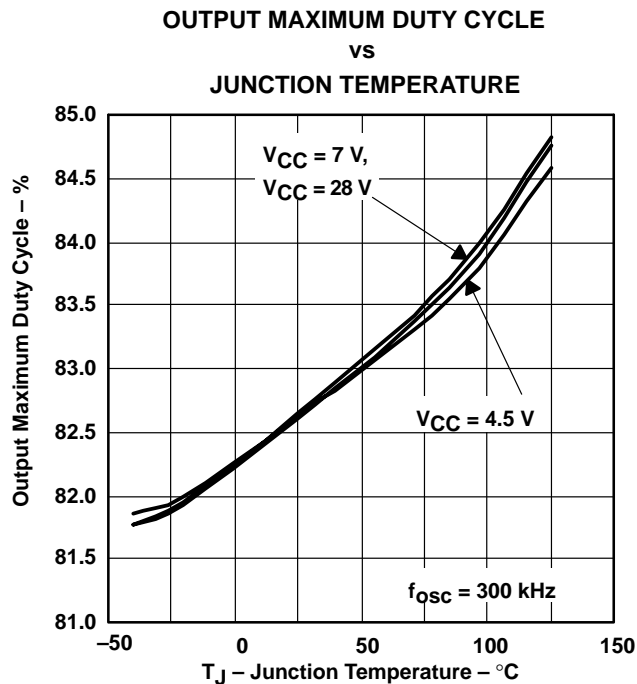
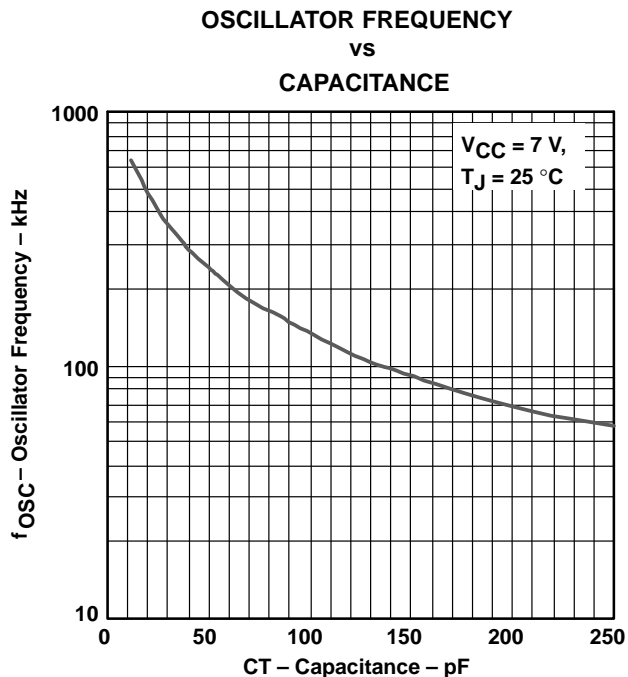


TPS5120

DUAL OUTPUT, TWO-PHASE SYNCHRONOUS BUCK DC/DC CONTROLLER

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TYPICAL CHARACTERISTICS



TPS5120 DUAL OUTPUT, TWO-PHASE SYNCHRONOUS BUCK DC/DC CONTROLLER

SLVS278E – AUGUST 2000 – REVISED MARCH 2003

TYPICAL CHARACTERISTICS

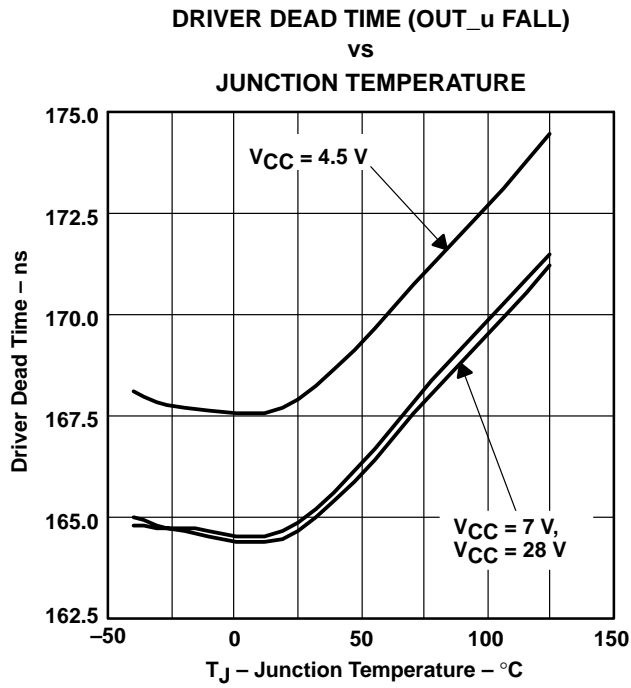


Figure 30

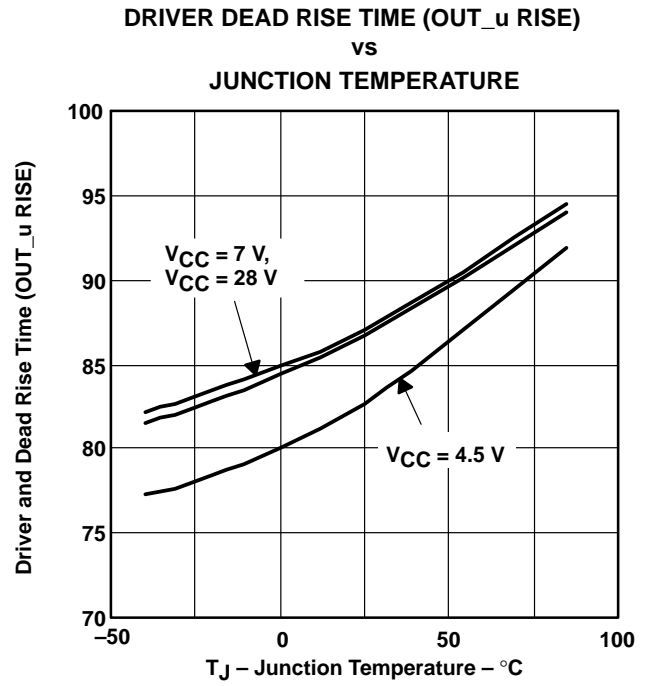


Figure 31

TPS5120

DUAL OUTPUT, TWO-PHASE SYNCHRONOUS BUCK DC/DC CONTROLLER

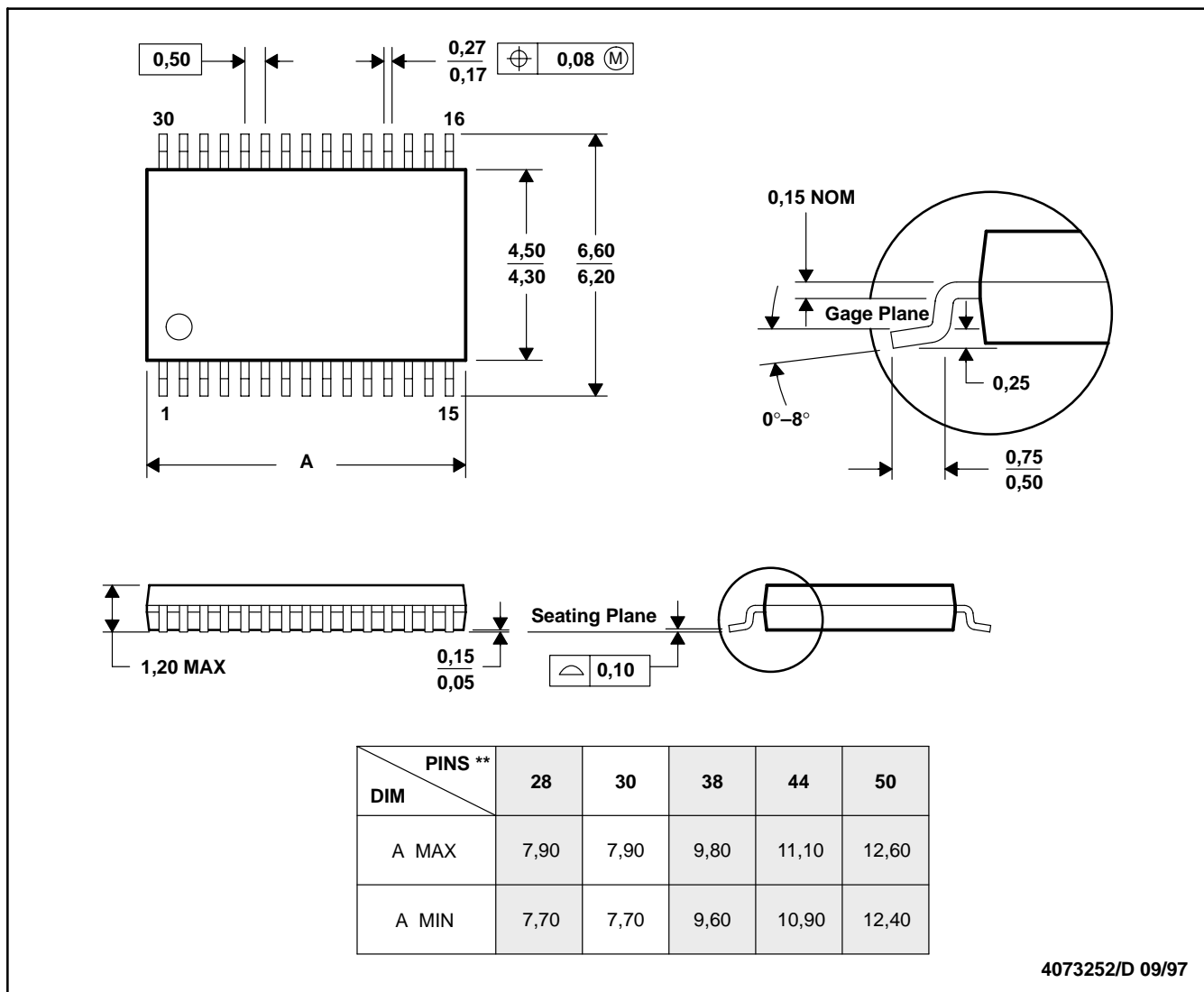
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MECHANICAL DATA

DBT (R-PDSO-G**)

PLASTIC SMALL-OUTLINE PACKAGE

30 PINS SHOWN



- NOTES: A. All linear dimensions are in millimeters.
 B. This drawing is subject to change without notice.
 C. Body dimensions do not include mold flash or protrusion.
 D. Falls within JEDEC MO-153

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