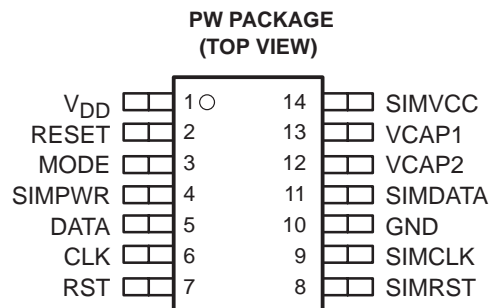


# TPS9125 5 V/3 V SIM SUPPLY AND LEVEL SHIFTERS

SLVS244A – SEPTEMBER 1999 – REVISED NOVEMBER 1999

- Integrated SIM Supply and Level Shifters
- Selectable 5-V or 3-V SIM Supply Voltage
- 3-V to 5-V Level Shifters, Bidirectional for SIM Data Line
- 10 kV ESD Protection (HBM) on SIMDATA, SIMRST, and SIMCLK Terminal
- 14 Terminal TSSOP
- Minimum Supply Voltage 2.7 V
- Integrated PullUp Resistor for DATA and SIMDATA
- Thin Shrink, Small Outline, Left-Hand Tape and Reel Package



## description

The TPS9125 SIM supply and level shifter integrates a programmable 3-V or 5-V SIM supply, conformable to the (GSM) test specification 11.10, together with either a 3-V or 5-V level shifter, conformable to the GSM specification 11.11 and 11.12.

A charge pump, utilizing two external capacitors, is configured as voltage doubler to generate a 5-V supply rail from V<sub>DD</sub>. Dependent on the SIM card used, a control signal coming from the SIM card controller is applied on the MODE terminal to switch between a 3-V or 5-V supply on the SIMVCC output terminal.

A 3-V/5-V bidirectional level shifter translates the 3-V compatible logic signal on DATA terminal into a 5-V compatible logic signal SIMDATA terminal, and vice versa. RST and CLK are unidirectional level shifters, providing a 5-V SIMRST and SIMCLK signal from the microcontroller to the SIM card.

The SIM supply is operating provided SIMPWR = 1 and V<sub>DD</sub> is sufficient (> 2.7 V). Under this condition, SIMVCC voltage is generated by the SIM supply charge pump.

A RESET terminal is provided for security reasons to switch off the SIM supply and interface if the SIM card is disconnected or removed by accident.

The TSP9125 is packaged in TI's thin shrink small-outline package (PW).

### AVAILABLE OPTIONS

T <sub>A</sub>	PACKAGE (PW)
-30°C to 85°C	TSP9125PWR†

† Suffix R stands for left-handed tape and reel.



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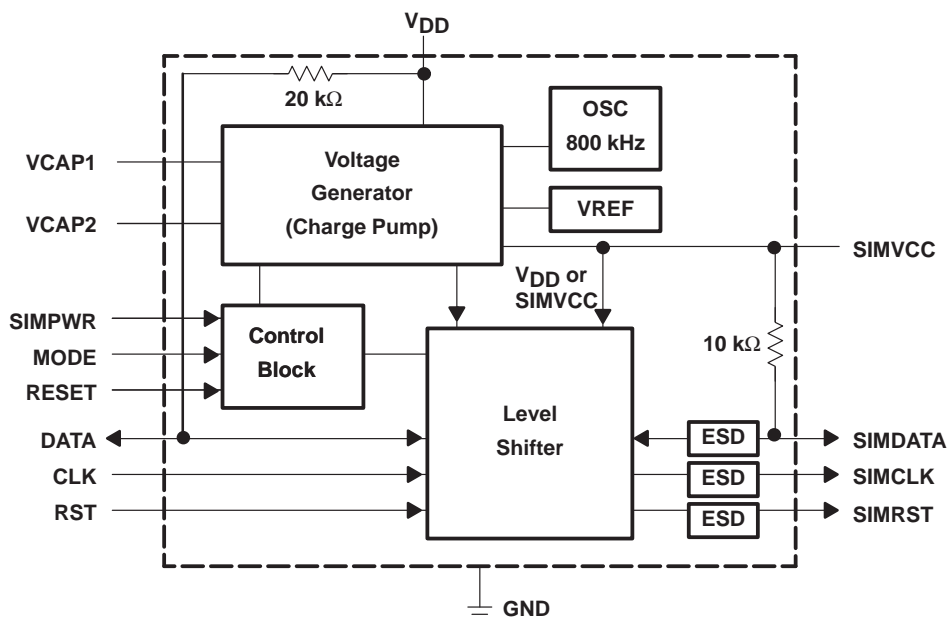
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# TPS9125

## 5 V/3 V SIM SUPPLY AND LEVEL SHIFTERS

SLVS244A – SEPTEMBER 1999 – REVISED NOVEMBER 1999

### functional block diagram



### Terminal Functions

TERMINAL NAME	NO.	I/O	DESCRIPTION
CLK	6	DI	3-V SIM clock signal. This terminal is connected to the SIM interface and works with 3-V logic level.
DATA	5	DI/O	3-V bidirectional data line. This terminal is connected to the SIM interface and works with 3-V logic level.
GND	10		Ground
MODE	3	DI	Programs the SIM supply voltage to $SIMV_{CC} = 5\text{ V}$ (MODE = 0) or $SIMV_{CC} = 3\text{ V}$ (MODE = 1).
RESET	2	DI	Reset for the TSP9125 SIM supply and interface in case the SIM is removed under operation.
RST	7	DI	3-V SIM reset signal. This terminal is connected to the SIM interface and works with 3-V logic level.
SIMCLK	9	DO	3-V/5-V SIM clock signal. This terminal is connected to the SIM reader contacts.
SIMRST	8	DO	3-V/5-V SIM reset signal. This terminal is connected to the SIM reader contacts.
SIMDATA	11	DI/O	3-V/5-V bidirectional data line. This terminal is connected to the SIM reader contacts.
SIMVCC	14		SIM supply voltage. Can be switched between $5\text{ V} \pm 10\%$ and $3\text{ V} \pm 10\%$ . This terminal is connected to the SIM reader contacts. Connect a $1\text{ }\mu\text{F} \pm 20\%$ capacitor between SIMVCC and GND.
SIMPWR	4	DI	SIM supply enable terminal. SIMPWR = 0 leaves SIMVCC open, SIMPWR = 1 enables SIM supply.
VCAP1	13		Charge pump capacitor. Connect $220\text{ nF} \pm 20\%$ capacitor between VCAP1 and VCAP2.
VCAP2	12		Charge pump capacitor. Connect $220\text{ nF} \pm 20\%$ capacitor between VCAP1 and VCAP2.
VDD	1		Supply voltage input. Connect a power bypass capacitor of $1\text{ }\mu\text{F}$ between VDD and GND. Connect capacitor physically close to the VDD terminal.

## detailed description

### voltage generator (charge pump)

The voltage generator can be programmed in two modes:

1. SIMPWR = 0: SIMVCC is left open, voltage generator disabled.
2. SIMPWR = 1: Depending on the signal on control terminal MODE, SIMVCC is either programmed to:
  - a. MODE = 0: 5 V ±10% (this is the default condition under which the system powers up),  
or
  - b. MODE = 1: SIMV<sub>CC</sub> is equal to the supply voltage V<sub>DD</sub> minus a voltage drop of 50 mV maximum.

The setting of the SIMVCC voltage (MODE = 0 or 1) can only be changed when SIMPWR is low. Therefore, as specified in GSM11.12, supply voltage switching is performed by deactivating the SIM and activating it at the new supply voltage.

In 5-V mode, a regulated charge pump is used to step-up the 3-V supply rail (min 2.7 V) to the 5-V supply rail. The voltage generator uses two external capacitors, one pump capacitor connected between VCAP1 and VCAP2 and one output buffer capacitor connected between SIMVCC and GND. It operates at a nominal frequency of 800 kHz, and also supplies the integrated level shifters to allow for 5-V compatible logic signals on SIMRST, SIMCLK, and SIMDATA.

In 3-V mode, the supply voltage V<sub>DD</sub> is connected via an integrated PMOS switch to the SIMVCC output. The charge pump, oscillator, and voltage reference are disabled in the 3-V mode to reduce power consumption. The supply voltage of the integrated level shifters is V<sub>DD</sub> minus a voltage drop of 50 mV maximum.

### control block

The control block uses the three control signals SIMPWR, MODE, and RESET to set the TSP9125 operation modes.

When SIMPWR is set low, the TSP9125 goes to power-down mode. To comply with the ISO/IEC 7816-3 specification for deactivation of the SIM contacts, the input terminals RST, DATA, and CLK must be low before the SIMPWR terminal is allowed to be taken low. When SIMPWR is low, the SIMRST, SIMDATA, and SIMCLK terminals are kept low and SIMVCC is left open.

The RESET input is used to disable the TSP9125 in case the SIM card is removed from the reader under operation. The input is therefore typically connected to a mechanical or other device used to detect the removal of the SIM card. When RESET is taken low, the SIMDATA, SIMCLK, and SIMRST terminals are taken low and SIMVCC is left open, until RESET is taken high again.

**Table 1. Control Block Function Table**

RESET	MODE	SIMPWR	OPERATING MODE
0	X	X	SIM supply disabled; SIMVCC open; SIMRST and SIMCLK and SIMDATA low
1	0	0	TSP9125 in power-down mode. SIM supply disabled; SIMVCC open; SIMRST, SIMCLK, and SIMDATA low; SIMVCC programmed to 5-V mode.
1	1	0	TSP9125 in power-down mode. SIM supply disabled; SIMVCC open; SIMRST, SIMCLK, and SIMDATA low; SIMVCC programmed to 3-V mode.
1	X	1	TSP9125 in normal operation mode; SIM supply enabled, SIMV <sub>CC</sub> = 5 V or 3 V depending on how it was programmed.

# TPS9125

## 5 V/3 V SIM SUPPLY AND LEVEL SHIFTERS

SLVS244A – SEPTEMBER 1999 – REVISED NOVEMBER 1999

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### detailed description (continued)

#### level shifters

The level shifters on TSP9125, when operating in the 5-V mode, convert a 3-V compatible logic signal from a digital control chip (SIM Controller) into a 5-V compatible logic signal for the SIM Card.

Operating in the 3-V mode, the level shifters are disabled and only pass the signal through.

The level shifters for reset and clock signal are unidirectional (RST to SIMRST, CLK to SIMCLK). The level shifter for the data signal is bidirectional, enabling signal exchange in both directions (DATA to SIMDATA and SIMDATA to DATA).

During power up and power down of the TSP9125, the voltage level on the SIMRST, SIMCLK, and SIMDATA terminals is kept below 0.4 V for currents less than 1 mA flowing into the TSP9125, provided  $V_{DD}$  is applied.

#### pullup resistors

The DATA and SIMDATA I/O pullup resistors are integrated in the device. The DATA resistor is 20 k $\Omega$  and the SIMDATA resistor is 10 k $\Omega$ .

#### oscillator

An integrated RC oscillator provides the charge pump with a nominal clock frequency of 800 kHz.

#### voltage reference

An integrated bandgap reference provides a reference voltage of 1.192 V to the charge pump to control and regulate the output voltage.

#### ESD protection

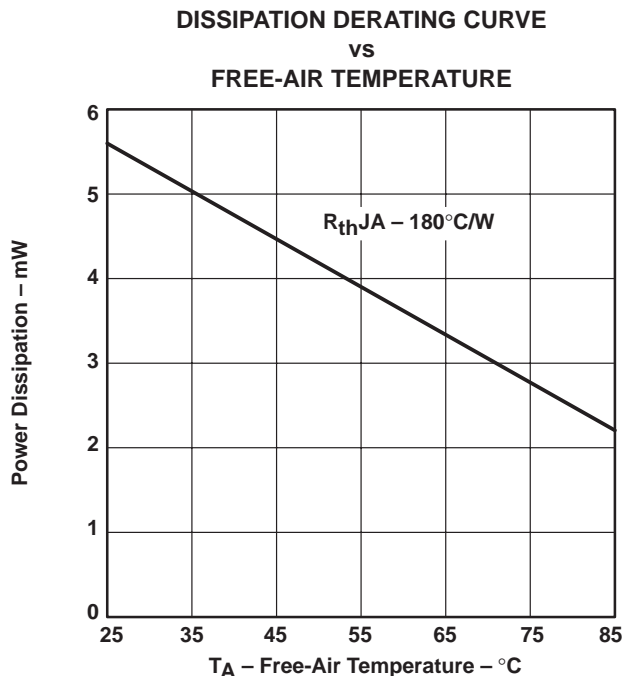
In a cellular telephone (GSM phone) the SIMRST, SIMCLK, and SIMDATA terminals are connected directly to the contacts of the SIM reader. This means they are accessible from the outside and therefore require increased ESD protection. The terminals withstand 10 kV ESD when tested according to human body model (HBM), 100 pF through 1500  $\Omega$ .

DISSIPATION RATING TABLE

PACKAGED	$T_A < 25^\circ\text{C}$ POWER RATING	OPERATING FACTOR ABOVE $T_A = 25^\circ\text{C}$	$T_A = 70^\circ\text{C}$ POWER RATING
PW	556 mW	5.56 mW/ $^\circ\text{C}$	306 mW



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

Supply voltage range, $V_{DD}$ .....	-0.3V to 4 V
Input voltage range, all other terminals .....	-0.3V to $V_{DD} + 0.3V$
Peak output current, $SIMV_{CC}$ .....	20 mA
Free-air temperature range .....	-40°C to 85°C
Storage temperature range .....	-60°C to 125°C
Continuous total power dissipation .....	0.1 W

† 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.

**recommended operating conditions**

	MIN	NOM	MAX	UNIT
Supply voltage, $V_{DD}$	2.7	3	3.3	V
Charge pump capacitor between VCAP1 and VCAP2		220		nF
Charge pump output capacitor on $SIMV_{CC}$	1			$\mu$ F
Input capacitor on $V_{DD}$	0.1	1		$\mu$ F
Operating free-air temperature range	-30		85	°C
Operating virtual junction temperature range	-30		125	°C
ESD susceptibility				kV
$SIMRST$ , $SIMCLK$ , $SIMDATA$ (human body model, 100 pF through 1500 $\Omega$ )	10 (TBC)			kV
All other terminals (human body model, 100 pF through 1500 $\Omega$ )	2			

# TPS9125

## 5 V/3 V SIM SUPPLY AND LEVEL SHIFTERS

SLVS244A – SEPTEMBER 1999 – REVISED NOVEMBER 1999

electrical characteristics over recommended operating junction temperature range,  $V_{DD} = 3\text{ V}$ ,  $C_{VCAP1/2} = 220\text{ nF} \pm 20\%$ ;  $C_{SIMVCC} = 1\text{ }\mu\text{F} \pm 20\%$ ;  $SIMPWR = 1$  (unless otherwise noted)

### voltage generator charge pump (SIMVCC)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Output voltage at SIMVCC, 5-V mode	$2.7\text{ V} < V_{DD} < 3.3\text{ V}$ , $I_{SIMVCC} = 10\text{ mA}$ , $f_{SIMCLK} = 0\text{ MHz}$ , $MODE = 0$ (default value)	4.5		5.5	V
Output voltage at SIMVCC, 3-V mode	$2.7\text{ V} < V_{DD} < 3.3\text{ V}$ , $I_{SIMVCC} = 6\text{ mA}$ , $MODE = 1$	$V_{DD} - 50\text{ mV}$		$V_{DD} - 50\text{ mV}$	V
Output current at SIMVCC, 5-V mode (see Note 1)	$2.7\text{ V} < V_{DD} < 3.3\text{ V}$			10	mA
Output current at SIMVCC, 3-V mode (see Note 1)	$2.7\text{ V} < V_{DD} < 3.3\text{ V}$			6	MA
Switching frequency (internal oscillator frequency)		440	800	1160	kHz
Output ripple	5-V mode, $I_{out} = 10\text{ mA}$			100	mV
Startup time	Standby to 5-V mode			1	ms
Power efficiency	$I_{SIMVCC} = 10\text{ mA}$		82.5%		

NOTE 1: The SIM supply circuit is designed according to the GSM specification 11.11 and 11.12 and complies to the requirements of GSM test specification 11.10. For more information, please see application section.

### level shifters (see Note 2)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Clock frequency CLK/SIMCLK	5-V mode	1		5	MHz
	3-V mode	1		4	
Clock duty cycle on SIMCLK	5-V mode and 3-V mode, CLK input 50% duty cycle	40%	50%	60%	
Output load, driver side			70	100	pF
Data rate on DATA/SIMDATA			Clk/372	Clk/32	MHz
Residual voltage at SIMRST, SIMCLK, SIMDATA in powerdown mode	$SIMPWR = 0$ , $I = 8\text{ }\mu\text{A}$	-0.4		0.4	V

NOTE 2: The level shifters are designed according to the GSM specification 11.11 and 11.12.

### logic inputs (CLK, MODE, RESET, RST, SIMPWR) (see Note 3)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_{IH}$ High-level input voltage		$0.7 \times V_{DD}$			V
$V_{IL}$ Low-level input voltage				$0.3 \times V_{DD}$	V
Input capacitance				10	pF
Input current		-20	-10	1	
Input leakage current	$V_{IN} = 0.5\text{ V to }3\text{ V}$	-1		1	

NOTE 3: For each state  $V_{IH}$ ,  $V_{IL}$ , a positive current is defined as flowing out of the TPS9125.

### logic output SIMCLK in 3-V mode (according to GSM 11.12) (see Note 4)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_{OH}$ High-level output voltage	$I_{OHmax} = 20\text{ }\mu\text{A}$	$0.7 \times SIMVCC$		$SIMVCC$	V
Low-level output voltage	$I_{OLmax} = -20\text{ }\mu\text{A}$	0		$0.2 \times SIMVCC$	V
Rise/fall time SIMCLK (see Note 5)	$C_{in} = C_{out} = 100\text{ pF}$			50	ns

NOTES: 4. For each state  $V_{OH}$ ,  $V_{OL}$ , a positive current is defined as flowing out of the TPS9125.

5. To allow for overshoot the voltage on SIMCLK should remain between  $-0.3\text{ V}$  and  $SIMVCC + 0.3\text{ V}$  during dynamic operations.



electrical characteristics over recommended operating junction temperature range,  $V_{DD} = 3\text{ V}$ ,  $C_{VCAP1/2} = 220\text{ nF} \pm 20\%$ ;  $C_{SIMVCC} = 1\text{ }\mu\text{F} \pm 20\%$ ;  $SIMPWR = 1$  (unless otherwise noted) (continued)

**logic output SIMCLK in 5-V mode (according to GSM 11.11)**

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_{OH}$ High-level output voltage (see Note 4)	$I_{OHmax} = 20\text{ }\mu\text{A}$	$0.7 \times SIMVCC$		$SIMVCC$	V
$V_{OL}$ Low-level output voltage (see Note 4)	$I_{OLmax} = -200\text{ }\mu\text{A}$	0		0.5	V
$t_r/t_f$ Rise/fall time SIMCLK (see Note 5 and 6)	$C_{in} = C_{out} = 100\text{ pF}$ , $f_{SIMCLK} = 5\text{ MHz}$			18	ns

- NOTES: 4. For each state  $V_{OH}$ ,  $V_{OL}$ , a positive current is defined as flowing out of the TSP9125.  
5. To allow for overshoot the voltage on SIMCLK should remain between  $-0.3\text{ V}$  and  $SIMVCC+0.3\text{ V}$  during dynamic operations.  
6. The maximum rise/fall time is 9% of the SIMCLK period.

**logic output SIMRST in 3-V mode (according to GSM 11.12)**

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_{OH}$ High-level output voltage (see Note 4)	$I_{OHmax} = 200\text{ }\mu\text{A}$	$0.8 \times SIMVCC$		$SIMVCC$	V
$V_{OL}$ Low-level output voltage (see Note 4)	$I_{OLmax} = -200\text{ }\mu\text{A}$	0		$0.2 \times SIMVCC$	V
$t_r/t_f$ Rise/fall time SIMRST (see Note 5)	$C_{in} = C_{out} = 100\text{ pF}$			400	$\mu\text{s}$

- NOTES: 4. For each state  $V_{OH}$ ,  $V_{OL}$ , a positive current is defined as flowing out of the TSP9125.  
5. To allow for overshoot the voltage on SIMCLK should remain between  $-0.3\text{ V}$  and  $SIMVCC+0.3\text{ V}$  during dynamic operations.

**logic output SIMRST in 5-V mode (according to GSM 11.11)**

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_{OH}$ High-level output voltage (see Note 4)	$I_{OHmax} = 200\text{ }\mu\text{A}$	$SIMVCC - 0.7\text{ V}$		$SIMVCC$	V
$V_{OL}$ Low-level output voltage (see Note 4)	$I_{OLmax} = -200\text{ }\mu\text{A}$	0		0.6	V
$t_r/t_f$ Rise/fall time SIMRST (see Note 5)	$C_{in} = C_{out} = 100\text{ pF}$			400	$\mu\text{s}$

- NOTES: 4. For each state  $V_{OH}$ ,  $V_{OL}$ , a positive current is defined as flowing out of the TSP9125.  
5. To allow for overshoot the voltage on SIMCLK should remain between  $-0.3\text{ V}$  and  $SIMVCC+0.3\text{ V}$  during dynamic operations.

**logic input/output DATA**

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_{IH}$ High-level input voltage on DATA (see Note 7)		$0.7 \times V_{DD}$			V
$V_{IL}$ Low-level input voltage on DATA (see Note 7)				$0.2 \times V_{DD}$	V
$V_{OH}$ High-level output voltage on DATA (see Note 7)	$I_{OHmax} = 20\text{ }\mu\text{A}$ , $V_{SIMDATA} = 3\text{ V}$	$0.7 \times V_{DD}$		$V_{DD}$	V
$V_{OL}$ Low-level output voltage on DATA (see Note 7)	$I_{OLmax} = -1\text{ mA}$ , $V_{SIMDATA} = 0\text{ V}$	0		0.4	V
$t_r/t_f$ Rise/fall time DATA (see Note 5)	$C_{in} = C_{out} = 100\text{ pF}$ , Integrated pullup resistor = $20\text{ k}\Omega$			1	$\mu\text{s}$

- NOTES: 5. To allow for overshoot the voltage on SIMCLK should remain between  $-0.3\text{ V}$  and  $SIMVCC+0.3\text{ V}$  during dynamic operations.  
7. For each state  $V_{OH}$ ,  $V_{OL}$ ,  $V_{IH}$ ,  $V_{IL}$ , a positive current is defined as flowing out of the TSP9125.

# TPS9125

## 5 V/3 V SIM SUPPLY AND LEVEL SHIFTERS

SLVS244A – SEPTEMBER 1999 – REVISED NOVEMBER 1999

electrical characteristics over recommended operating junction temperature range,  $V_{DD} = 3\text{ V}$ ,  $C_{VCAP1/2} = 220\text{ nF} \pm 20\%$ ;  $C_{SIMVCC} = 1\text{ }\mu\text{F} \pm 20\%$ ;  $SIMPWR = 1$  (unless otherwise noted) (continued)

### logic input/output SIMDATA in 3-V mode (according to GSM 11.12)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_{IH}$	High-level input voltage on SIMDATA (see Note 7)	$I_{IHmax} = \pm 20\text{ }\mu\text{A}$	$0.7 \times SIMVCC$		$SIMVCC + 0.3\text{ V}$	V
$V_{IL}$	Low-level input voltage on SIMDATA (see Note 7)	$I_{ILmax} = 1\text{ mA}$	-0.3		$0.2 \times SIMVCC$	V
$V_{OH}$	High-level output voltage on SIMDATA (see Note 7)	$I_{OHmax} = 20\text{ }\mu\text{A}$ , $V_{DATA} = 3\text{ V}$	$0.7 \times SIMVCC$		$SIMVCC$	V
$V_{OL}$	Low-level output voltage on SIMDATA (see Note 7)	$I_{OLmax} = -1\text{ mA}$ , $V_{DATA} = 0\text{ V}$	0		0.4	V
$t_r/t_f$	Rise/fall time SIMRST (see Note 5)	$C_{in} = C_{out} = 100\text{ pF}$ , Integrated pullup resistor = $10\text{ k}\Omega$			1	$\mu\text{s}$

NOTES: 5. To allow for overshoot the voltage on SIMCLK should remain between  $-0.3\text{ V}$  and  $SIMVCC + 0.3\text{ V}$  during dynamic operations.  
7. For each state  $V_{OH}$ ,  $V_{OL}$ ,  $V_{IH}$ ,  $V_{IL}$ , a positive current is defined as flowing out of the TSP9125.

### logic input/output SIMDATA in 5-V mode (according to GSM 11.12)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_{IH}$	High-level input voltage on SIMDATA (see Note 7)	$I_{IHmax} = \pm 20\text{ }\mu\text{A}$	$0.7 \times SIMVCC$		$SIMVCC + 0.3\text{ V}$	V
$V_{IL}$	Low-level input voltage on SIMDATA (see Note 7)	$I_{ILmax} = 1\text{ mA}$	-0.3		0.8	V
$V_{OH}$	High-level output voltage on SIMDATA (see Note 7)	$I_{OHmax} = 20\text{ }\mu\text{A}$ , $V_{DATA} = 3\text{ V}$	$0.7 \times SIMVCC$		$SIMVCC$	V
$V_{OL}$	Low-level output voltage on SIMDATA (see Note 7)	$I_{OLmax} = -1\text{ mA}$ , $V_{DATA} = 0\text{ V}$	0		0.4	V
$t_r/t_f$	Rise/fall time SIMRST (see Note 5)	$C_{in} = C_{out} = 100\text{ pF}$ , Integrated pullup resistor = $10\text{ k}\Omega$			1	$\mu\text{s}$

NOTES: 5. To allow for overshoot the voltage on SIMCLK should remain between  $-0.3\text{ V}$  and  $SIMVCC + 0.3\text{ V}$  during dynamic operations.  
7. For each state  $V_{OH}$ ,  $V_{OL}$ ,  $V_{IH}$ ,  $V_{IL}$ , a positive current is defined as flowing out of the TSP9125.

### supply current

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Powerdown/programming mode	$SIMPWR = 0$			5	$\mu\text{A}$
Ground current, operating	$SIMVCC = 5\text{ V}$ , $I_{SIMVCC} = 0\text{ mA}$			125	$\mu\text{A}$
	$SIMVCC = 5\text{ V}$ , $I_{SIMVCC} = 10\text{ mA}$		200		
	$SIMVCC = 3\text{ V}$ , $I_{SIMVCC} = 0\text{ mA}$			25	
	$SIMVCC = 3\text{ V}$ , $I_{SIMVCC} = 6\text{ mA}$		40		





PARAMETER MEASUREMENT INFORMATION

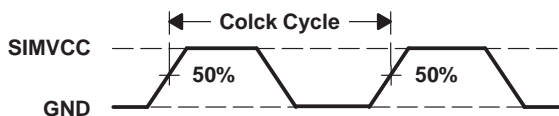


Figure 1. Clock Duty Cycle Measurement

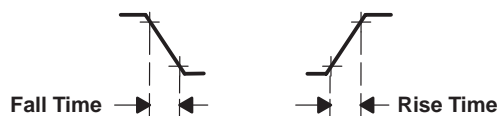


Figure 2. Rise and Fall Time Measurement

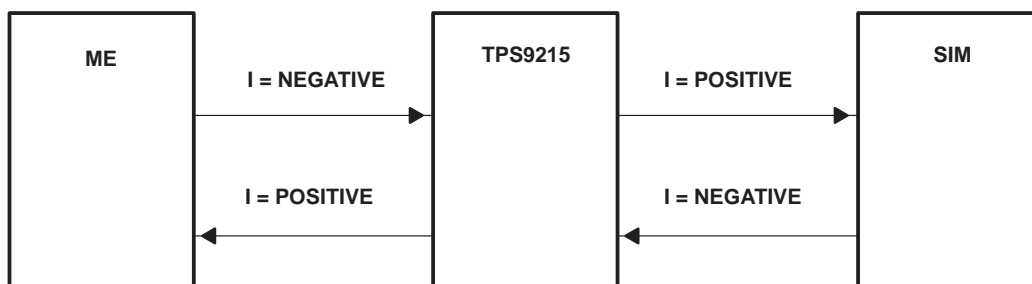


Figure 3. Current Direction Convention

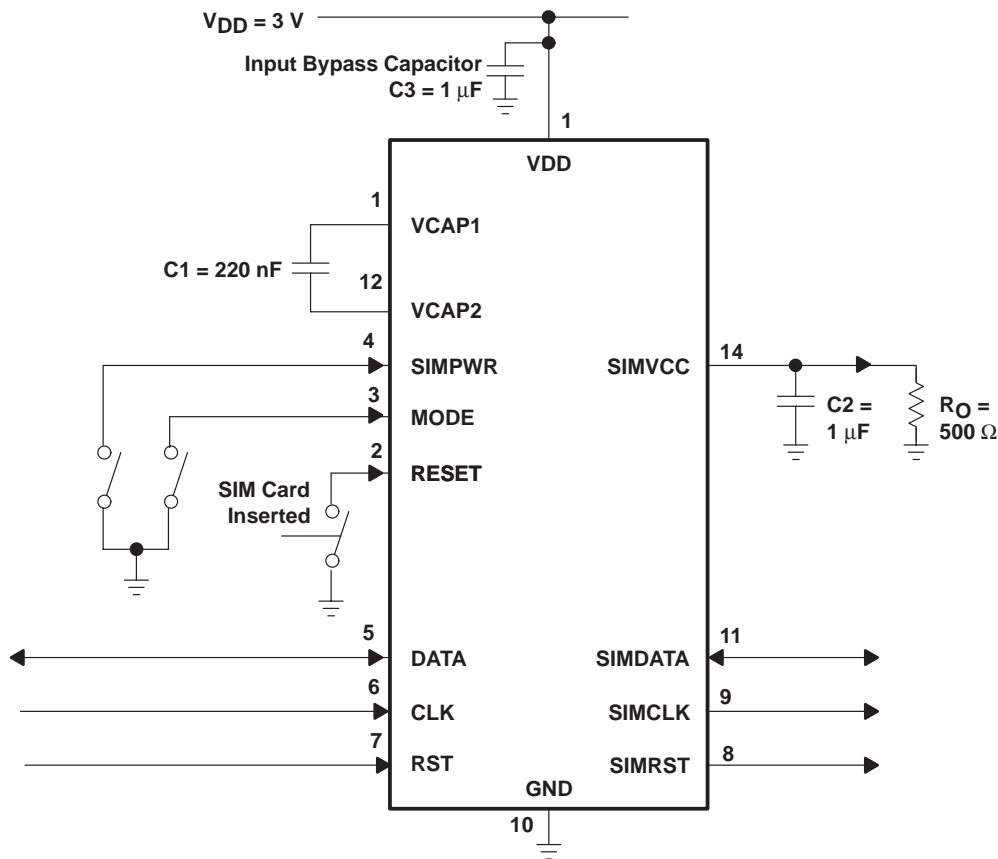


Figure 4. Parameter Measurement Information

# TPS9125

## 5 V/3 V SIM SUPPLY AND LEVEL SHIFTERS

SLVS244A – SEPTEMBER 1999 – REVISED NOVEMBER 1999

### PARAMETER MEASUREMENT INFORMATION

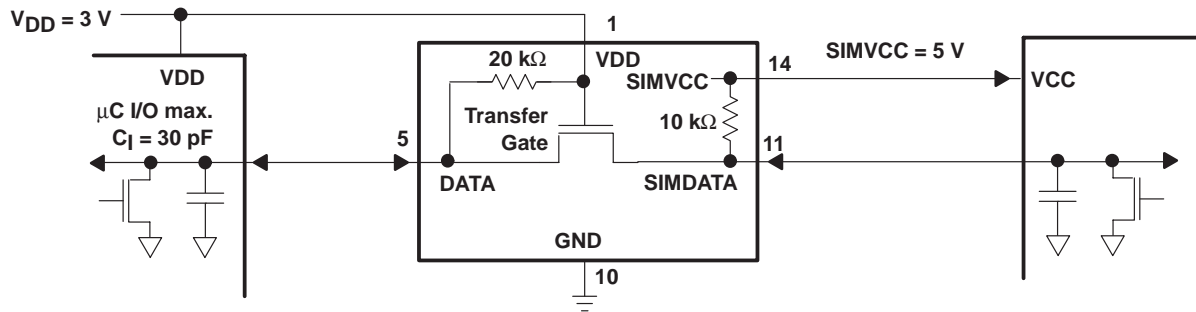


Figure 5. Parameter Measurement Information SIMDATA

The rise and fall time on DATA and SIMDATA signals depend on the I/O parameters of the used hardware (microcontroller and SIM card).

### TYPICAL CHARACTERISTICS

#### Table of Graphs

		FIGURE
Charge pump power loss	vs Output current on SIMV <sub>CC</sub>	6
Charge pump power efficiency	vs Output current on SIMV <sub>CC</sub>	7
Charge pump power efficiency	vs Supply voltage V <sub>DD</sub>	8
SIMV <sub>CC</sub> Charge pump performance	vs Supply voltage V <sub>DD</sub>	9

TYPICAL CHARACTERISTICS

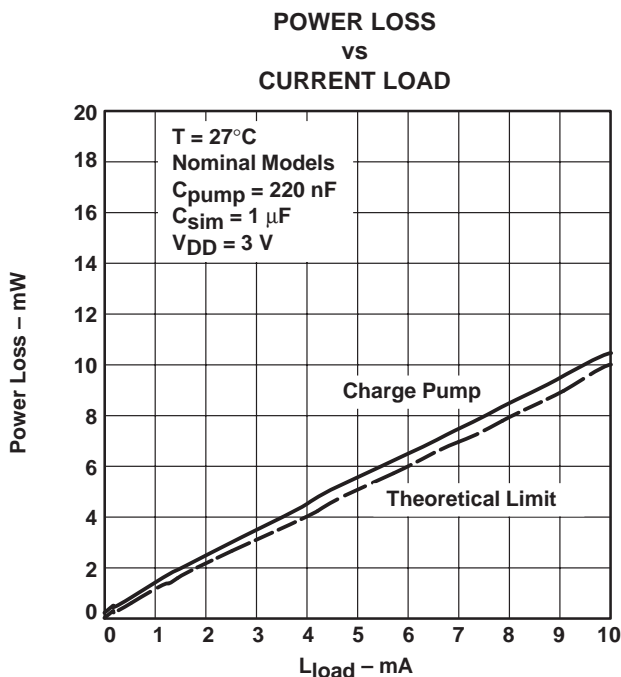


Figure 6

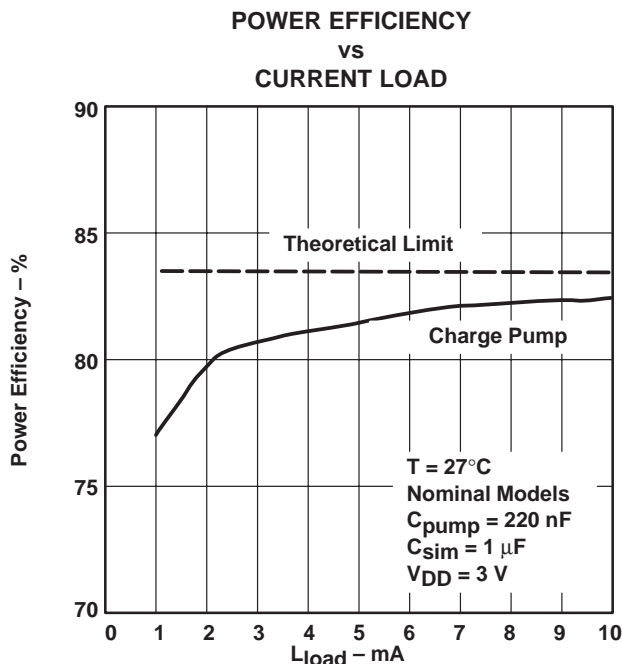


Figure 7

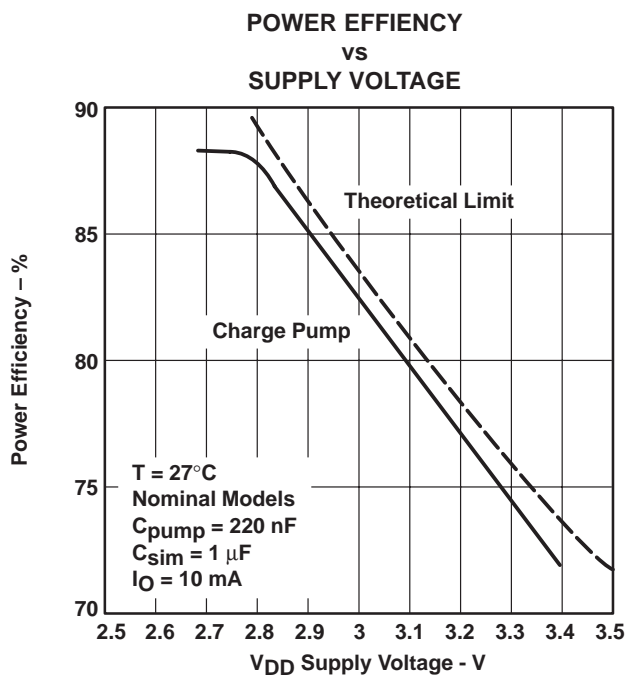


Figure 8

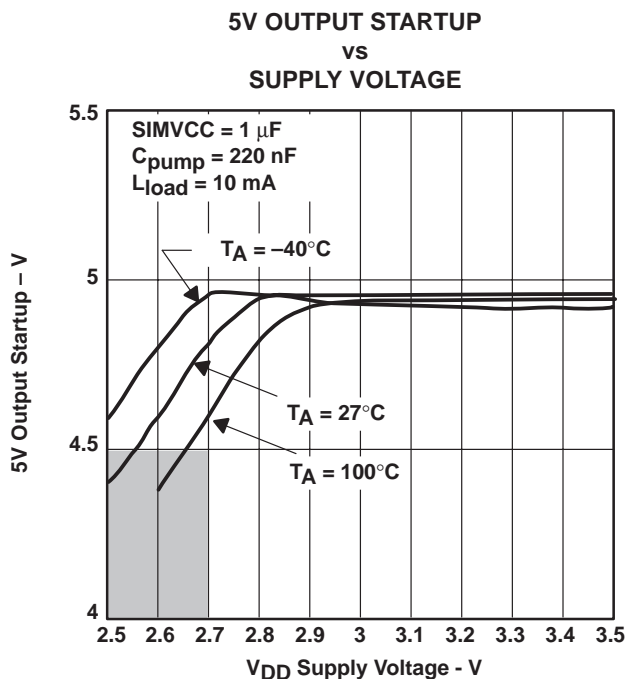


Figure 9

# TPS9125

## 5 V/3 V SIM SUPPLY AND LEVEL SHIFTERS

SLVS244A – SEPTEMBER 1999 – REVISED NOVEMBER 1999

### THERMAL INFORMATION

Implementation of integrated circuits in low profile and fine-pitch surface-mount packages requires special attention to power dissipation. Many system-dependent issues such as thermal coupling, airflow, added heat sinks and convection surfaces, as well as the presence of other heat-generating components, affect the power-dissipation limits of a given component.

Three basic approaches for enhancing thermal performance are listed below.

- Improving the power dissipation capability of the PWB design
- Improving the thermal coupling of the component to the PWB
- Introducing airflow in the system

Using the given  $R_{\theta JA}$  for this IC, the maximum power dissipation can be calculated with the equation:

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

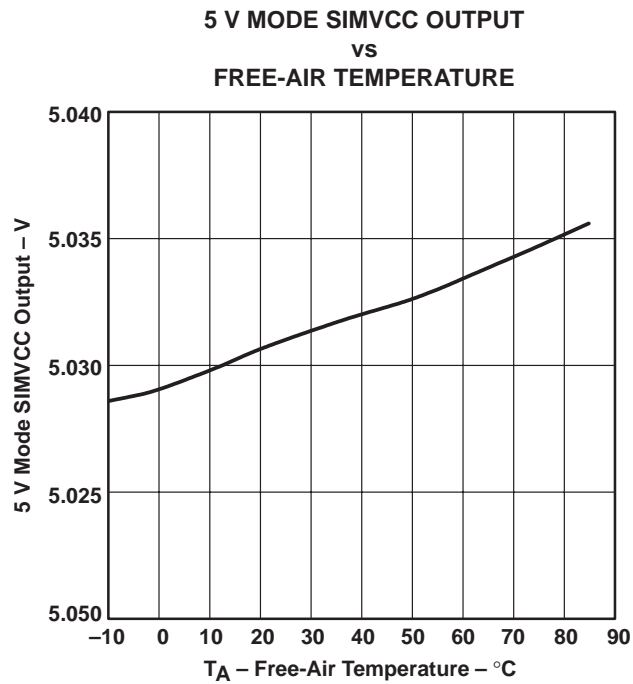


Figure 10

APPLICATION INFORMATION

charge pump terminal

The charge pump can be used to generate a negative voltage from a positive supply voltage, or to voltage-double, triple, or otherwise multiply the supply voltage. In the TSP9125, a charge pump is used to generate a 5-V supply rail from an input voltage of 3 V.

Figure 11 is used to explain the principle of a charge pump when configured as a voltage doubler.

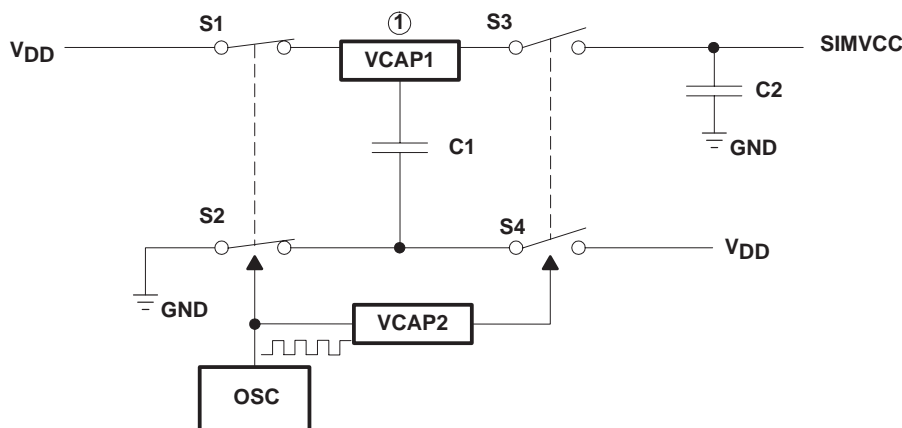


Figure 11. Principal of a Charge Pump Configured as a Voltage Doubler

During the first half of the oscillator period, switches S1 and S2 are closed, switches S3 and S4 are open, and the pump capacitor C1 is charged. In the second half of the oscillator period, switches S3 and S4 are closed and switches S1 and S2 are open. Immediately after closing the switches S3 and S4, the voltage at Node 1 is:

$$V_1 = V_{DD} + V_{C1} \approx 2 \times V_{DD}$$

assuming C1 was charged up to  $V_{DD}$ . In this half of the period, the pump capacitor C1 charges the output capacitor C2. After the start-up time, the output capacitor C2 is charged up to  $V_1$  and the voltage at SIMVCC is stable at this value, with only a small amount of ripple, which is normally around 1% of the supply voltage. The ripple depends on the oscillator frequency, the load on SIMVCC, and the size of output capacitor C2.

In practice, the voltage  $V_1$  is a little bit less than  $2 \times V_{DD}$  because of conduction losses across the switches and switching losses in capacitor C1.

An unregulated charge pump generates an output voltage that is only dependent on the supply voltage and the output current.

voltage generator

The charge pump used in the TSP9125 is regulated in such a way that the output voltage stays at  $5 V \pm 10\%$ , independently of the supply voltage and output current. A two-point regulator scheme was used to control the output voltage. In addition, it reduces power consumption. The charge pump is active and enabled as long as an oscillator frequency is applied. Figure 11 shows the functional block diagram of the voltage generator.

APPLICATION INFORMATION

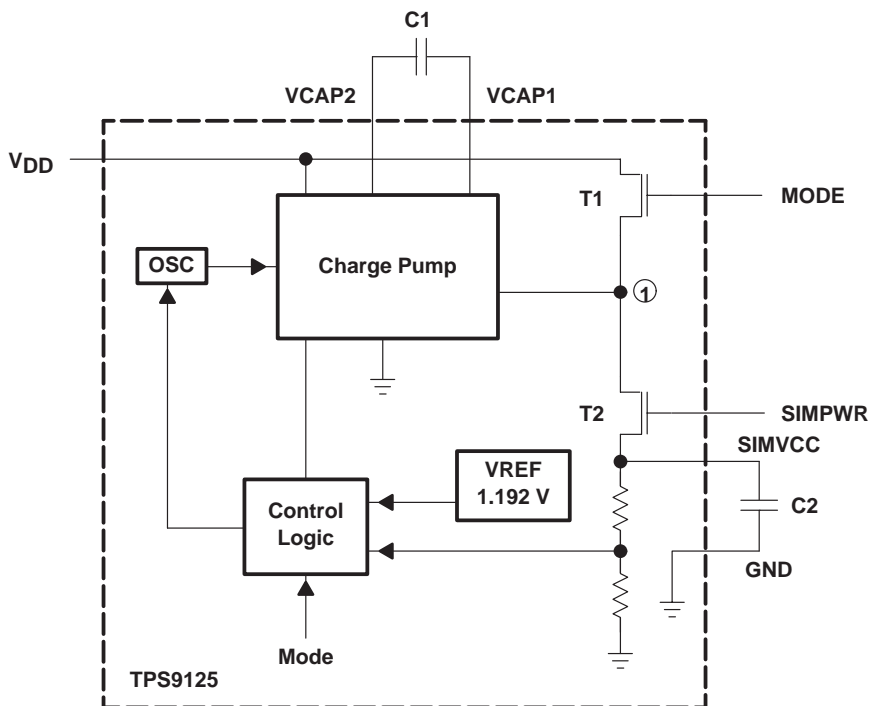


Figure 12. Functional Block Diagram of the Voltage Generator

When the TSP9125 is programmed in 5-V mode, the voltage at SIMVCC is monitored and regulated. If the voltage of SIMVCC exceeds a defined upper threshold, the charge pump is switched off by disabling the oscillator. In this state, all switching losses are zero, and the load is supplied only from the output capacitor C2. The charge pump and oscillator are reactivated if the voltage at SIMVCC drops below a defined lower threshold. In this state, the charge pump recharges output capacitor C2 until the voltage across C2 again exceeds the defined upper threshold. Figure 12 shows the waveform of the charge pump output SIMVCC in 5-V mode.

Using this control mechanism, the switching losses of the charge pump and the losses of the oscillator are minimized, because the charge pump and the oscillator are only activated when they are needed.

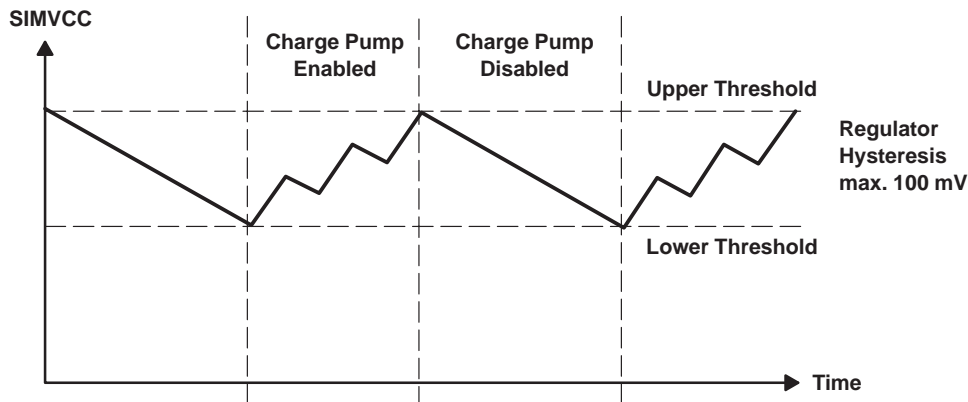


Figure 13. Typical Waveform at Charge Pump Output SIMVCC in 5-V Mode

APPLICATION INFORMATION

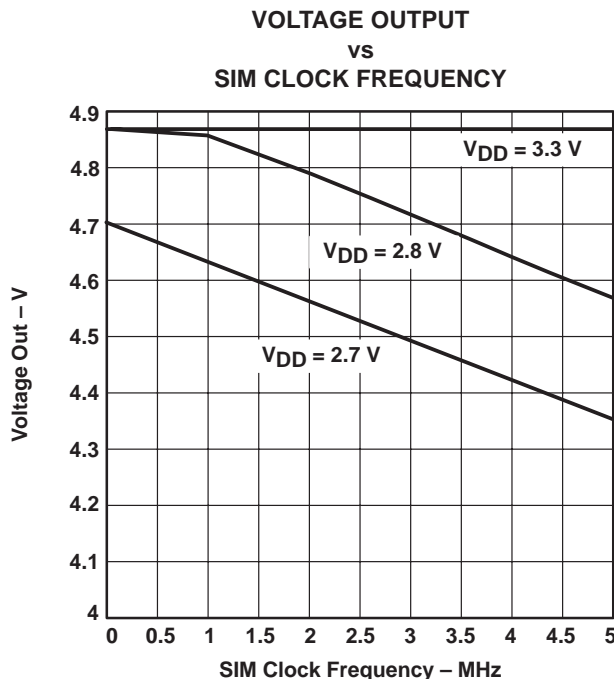


Figure 14. Voltage At SIMV<sub>CC</sub> vs Frequency at SIMCLK Terminal in 5-V Mode

Figure 14 shows the output voltage on SIMVCC in 5-V mode versus the frequency of the clock signal on CLK/SIMCLK dependent on the input voltage V<sub>DD</sub>. The load on the charge pump is the sum of the maximum dc load on SIMVCC (10 mA) and the ac load of 100 pF on SIMCLK buffer.

In 3 V mode, the charge pump and oscillator are disabled all the time, thus reducing power dissipation to a minimum. Switches T1 and T2 in Figure 14 directly connect the supply voltage on V<sub>DD</sub> to SIMVCC; the voltage on SIMVCC is therefore equal to the supply voltage V<sub>DD</sub> minus the conduction losses across the switches.

dimensioning of the capacitors

output capacitor C2

The value of output capacitor C2 depends on the maximum charge pump load current, the allowed ripple on SIMVCC, and the charge pump operating frequency.

In 5-V mode, the charge pump also supplies the drivers of the 5-V level shifters. The maximum load current the charge pump has to provide is therefore the sum of the dc output current at SIMVCC and the ac supply current for the level shifters; the SIMCLK driver is the major contributor to this ac load:

$$I_{LOADmax} = I_{SIMVCCmax} + I_{ACmax} = 10 \text{ mA} + 6 \text{ mA} = 16 \text{ mA}$$

The minimum, theoretical required value for C2 can be calculated using the equation below:

$$C2_{min} = \frac{I_{LOADmax} \times f}{V_{ripple}} = \frac{I_{LOADmax}}{V_{ripple} \times 2 \times f_{OSC}} = \frac{16 \text{ mA}}{100 \text{ mV} \times 2 \times 440 \text{ kHz}} = 185 \text{ nF}$$

As described above, the regulated charge pump is disabled during the time in which the voltage across the output capacitor C2 is above the lower threshold voltage, and therefore high enough to ensure the specified minimum voltage on SIMVCC.

# TPS9125

## 5 V/3 V SIM SUPPLY AND LEVEL SHIFTERS

SLVS244A – SEPTEMBER 1999 – REVISED NOVEMBER 1999

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### APPLICATION INFORMATION

#### output capacitor C2 (continued)

Increasing the value of the capacitor C2 will increase the time the charge pump is disabled. The power consumption of the charge pump will be reduced, because the active time in which switching losses occur is shorter. However, a larger value of C2 also results in a longer start-up time for the 5-V supply. Based on the above considerations a 1  $\mu$ F capacitor is recommended for C2.

#### pump capacitor C1

The value of pump capacitor C1 has a big impact on the start-up time of the charge pump: this is the time needed to charge the output capacitor C2 from 0 V up to 5 V. The recommended value for capacitor C1 is 220 nF, thus ensuring a start-up time of less than 1ms. If a lower value for capacitor C1 is chosen, the start-up time will increase.

#### input capacitor

During the activation time of the charge pump there are steep current slopes of about 40 mA on the supply input  $V_{DD}$ . Therefore, it is recommended to use a low ESR 1  $\mu$ F capacitor, such as a multilayer ceramic or tantalum capacitor, on the  $V_{DD}$  terminal.

#### capacitor selection

The exact capacitance value of the capacitors used is not as critical as the use of high quality and low ESR (equivalent serial resistance) capacitors, such as multilayer ceramic or tantalum capacitors.

The ESR of C1 causes a voltage drop during charging and discharging, and this degrades the performance of the charge pump. Low ESR is most critical for the choice of capacitor C1, because the charge current of this capacitor is twice as much as the load current and the current through output capacitor C2. If a tantalum capacitor is used for C1, the positive terminal should be connected to VCAP1.

The ESR of output capacitor C2 increases the ripple on SIMVCC. The ESR of C2 has only a minor influence, because the ripple on SIMVCC in the TSP9125 is fixed at maximum 100 mV, due to the two-point regulation scheme used. If a tantalum capacitor is used for C2, the positive terminal should be connected to SIMVCC.

#### pulsed output current

To comply with GSM test specification 11.10, paragraph 27.17.2.1.2, the SIMVCC supply voltage must stay above the minimum allowed voltage level when spikes in the current consumption of the card occur. For a 5-V SIM card interface, those spikes are up to a maximum charge of 40nAs. To test for this requirement, current pulses of maximum 400 ns duration and maximum 200 mA amplitude are drawn from SIMVCC. For a 3-V SIM card interface, those spikes are up to a maximum 12 mA charge. To test for this requirement, current pulses of maximum 400ns duration and maximum 60-mA amplitude are drawn from SIMVCC.

In 5-V mode (MODE = 0),  $SIMV_{CC}$  must stay above 4.5 V, in 3-V mode (MODE = 1), it must stay above 2.7 V. Because the TSP9125 charge pump itself is too slow to counteract these peaks, the correct combination of capacitors on SIMVCC must be chosen to cope with these requirements. In addition to the 1  $\mu$ F  $\pm$ 20% low ESR ceramic capacitor used to buffer the SIMVCC output, it is recommended to connect a 100 nF ceramic capacitor as close as possible to the contacting elements.





APPLICATION INFORMATION

enabling and disabling the TSP9125

The TSP9125 meets the deactivation requirements according to GSM 11.11 paragraph 4.3.2, and ISO/IEC 7816-3 paragraph 5.4. These specifications define that the I/O line of the SIM card must be pulled low before the supply voltage of the SIM card is deactivated. In 3-V and 5-V mode, the SIMDATA terminal of the TSP9125 is pulled low before SIMVCC is disabled.

During normal operation mode (3-V or 5-V) the SIMPWR and RESET inputs must be high. If one of these terminals is switched low, the supply of the SIM card is deactivated. In Figure 15 and Figure 16, the SIMPWR terminal is pulled low. The I/O line of the SIM card (SIMDATA) is pulled low immediately although DATA is high, whereas the supply voltage on SIMVCC decreases to approximately 2 V quickly and then needs about 100 ms to reach 0 V. Thus, when the operating mode is changed from the 5-V tsupply to the 3-V supply, the voltage on SIMVCC is decreased to a level below the supply voltage  $V_{DD}$  to prevent reverse current flow.

In Figure 15 to Figure 17, the RESET terminal is pulled low externally. Also in this situation, SIMDATA goes low immediately although the input signal at DATA is high.

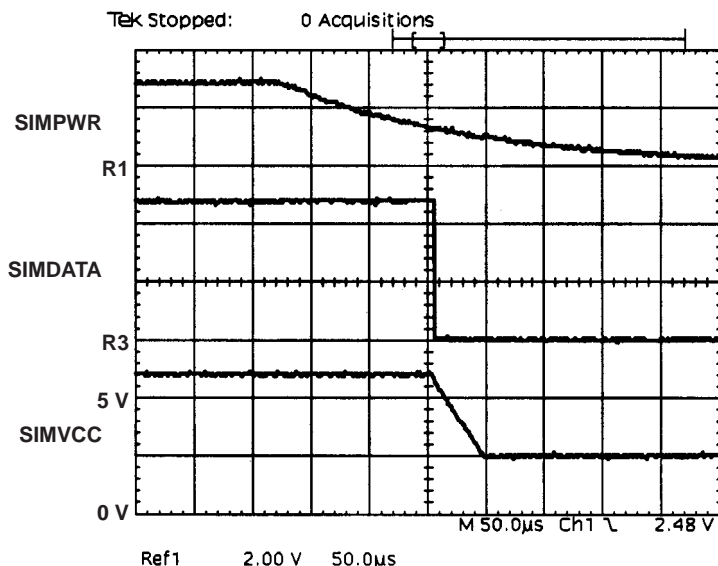


Figure 15. Powerdown Characteristic in 5-V mode vs Time: 50 µs/div

APPLICATION INFORMATION

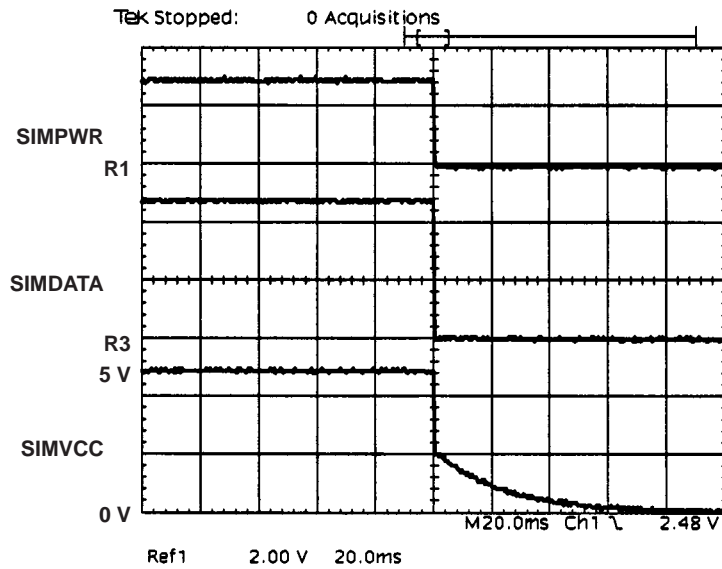


Figure 16. Power-Down Characteristic in 5-V Mode vs Time: 20 ms/div

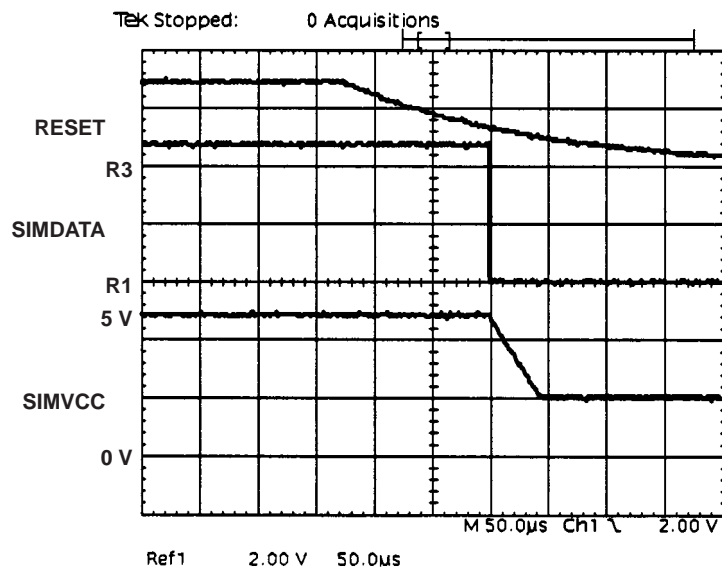


Figure 17. Reset Characteristic in 5-V Mode vs Time: 50 ms/div

APPLICATION INFORMATION

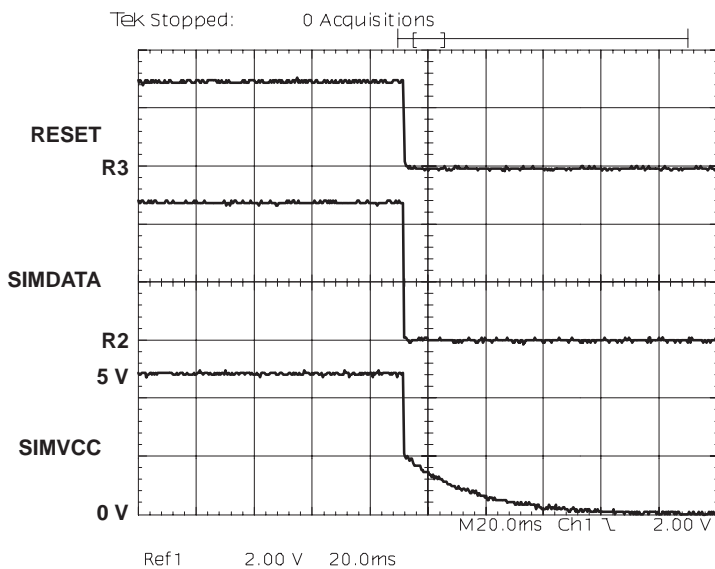


Figure 18. Reset Characteristic in 5-V Mode vs Time: 20  $\mu$ s/div

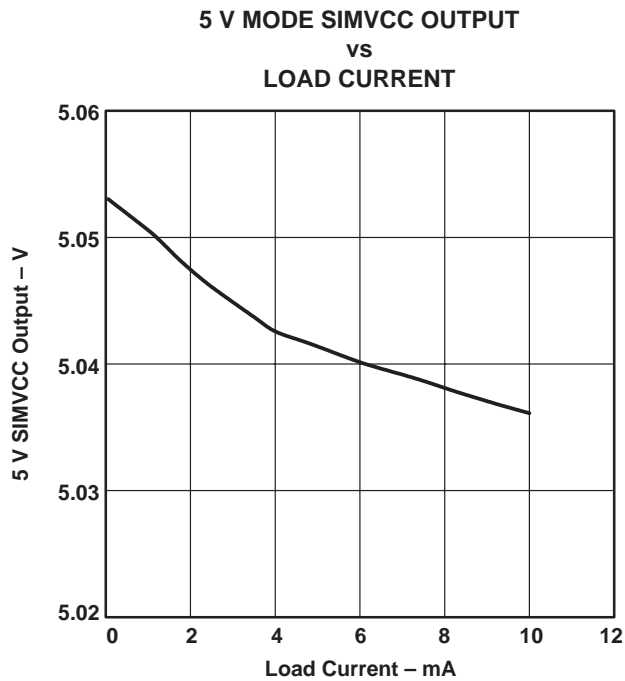


Figure 19

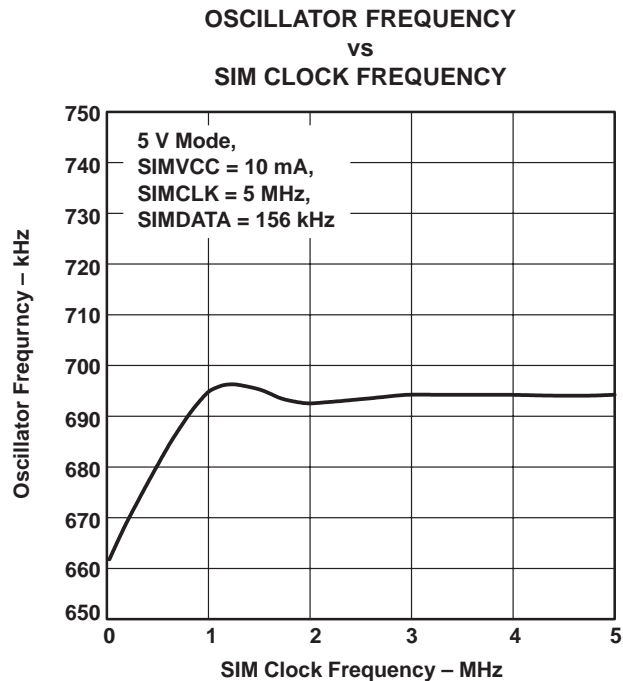


Figure 20

APPLICATION INFORMATION

5 V OUTPUT STARTUP  
VS  
TIME

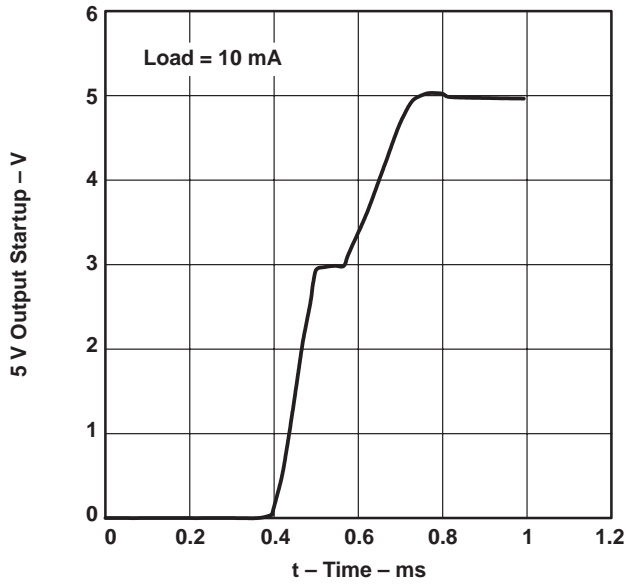


Figure 21

5 V OUTPUT SHUTDOWN  
VS  
TIME

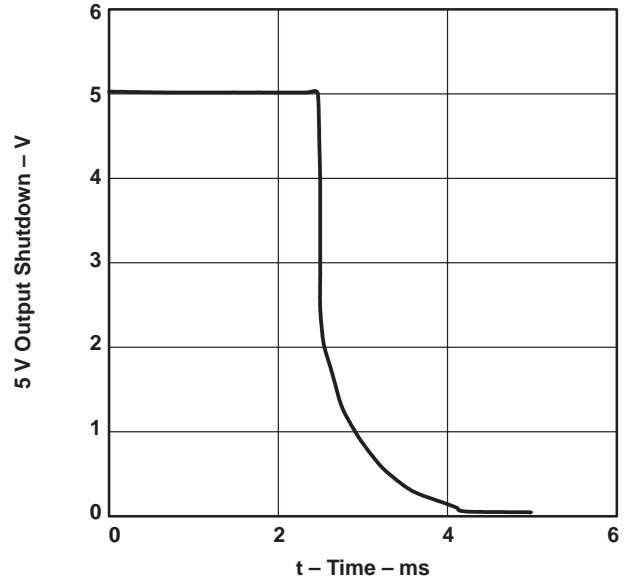


Figure 22

3 V OUTPUT STARTUP  
VS  
TIME

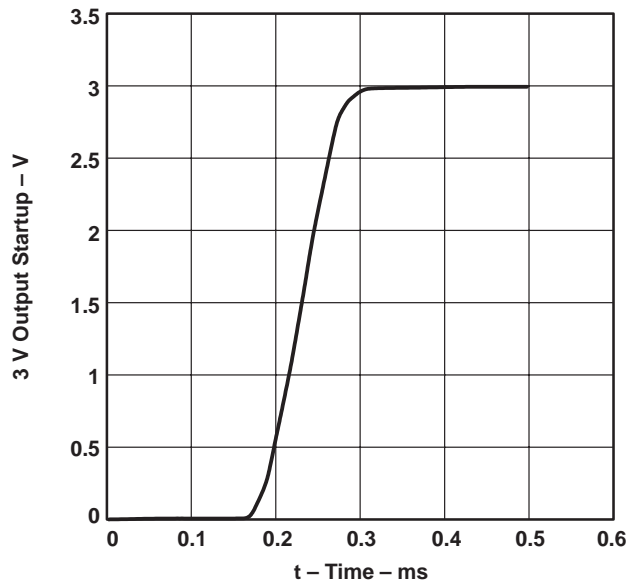


Figure 23

3 V OUTPUT SHUTDOWN  
VS  
TIME

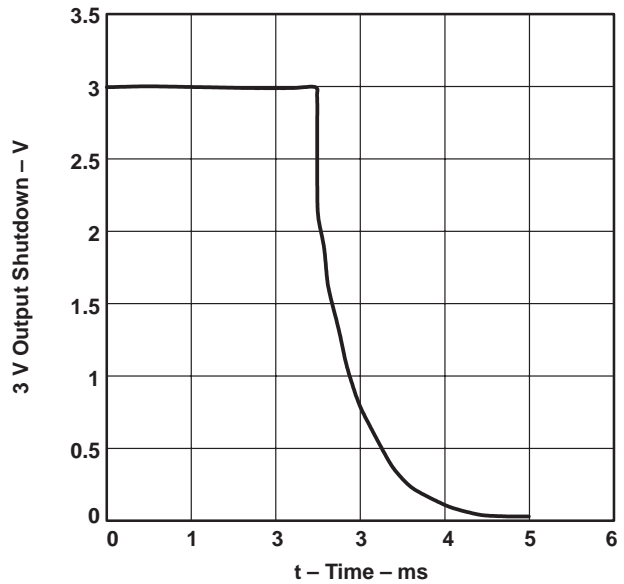


Figure 24

APPLICATION INFORMATION

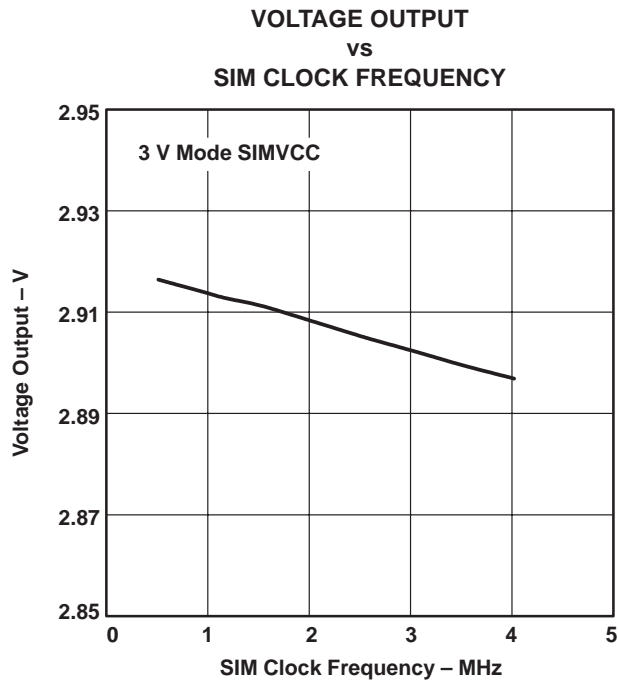


Figure 25

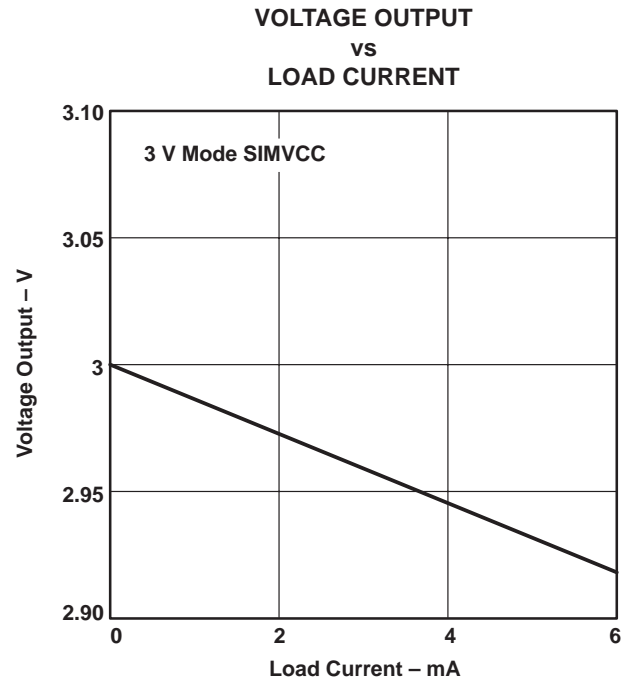


Figure 26

# TPS9125

## 5 V/3 V SIM SUPPLY AND LEVEL SHIFTERS

SLVS244A – SEPTEMBER 1999 – REVISED NOVEMBER 1999

### APPLICATION INFORMATION

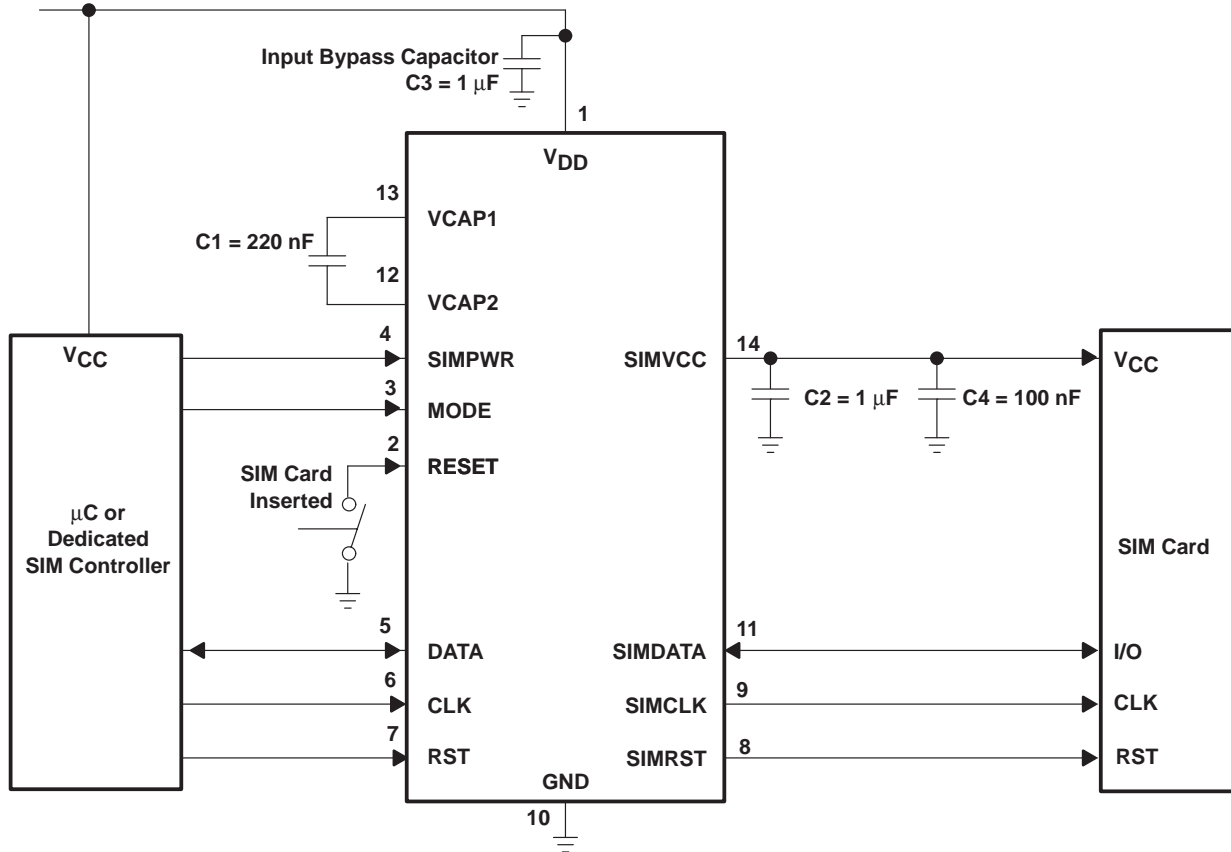


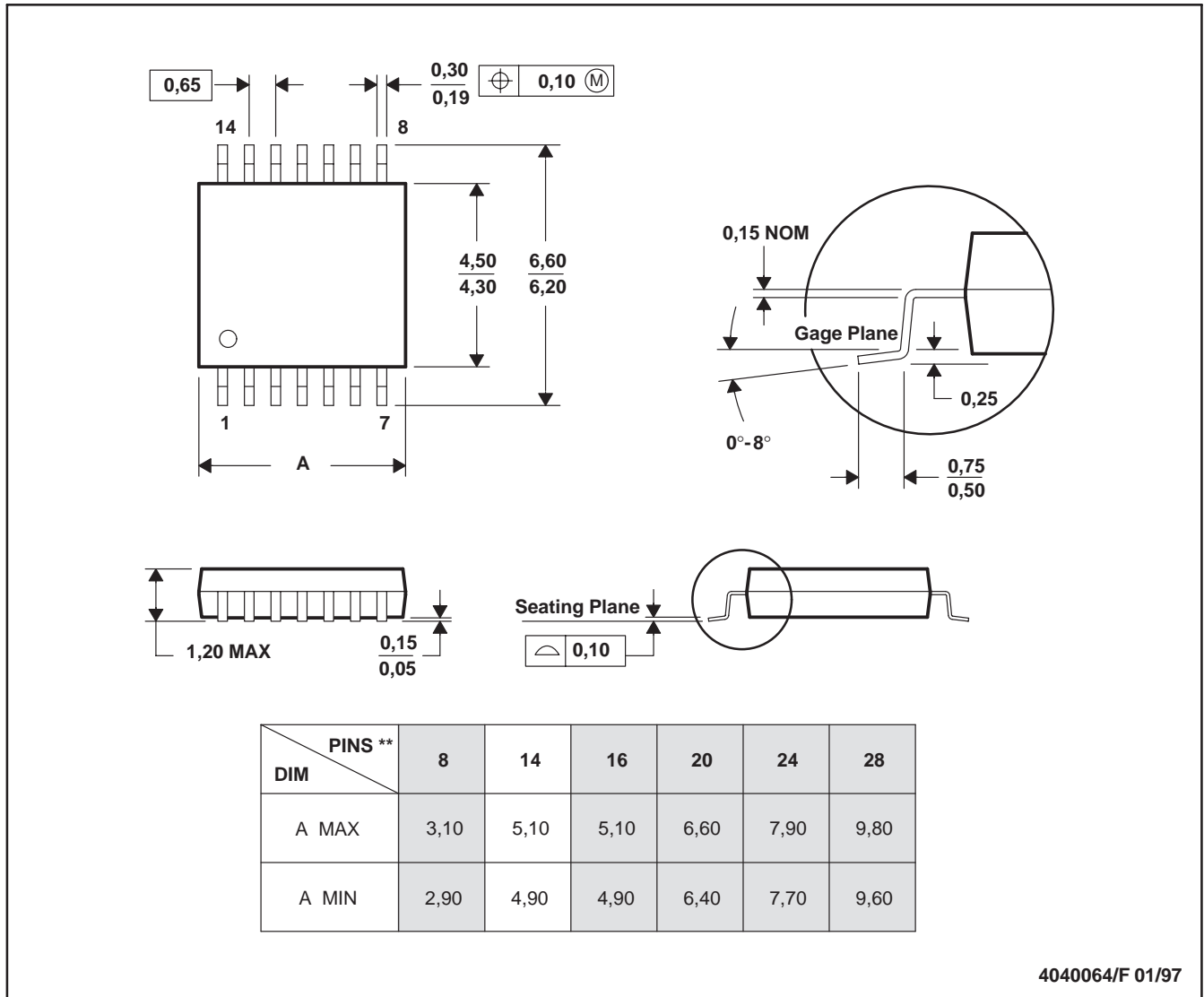
Figure 27. Typical Application

MECHANICAL DATA

PW (R-PDSO-G\*\*)

PLASTIC SMALL-OUTLINE PACKAGE

14 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 not to exceed 0,15.  
 D. Falls within JEDEC MO-153

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